LOOKING TO THE FUTURE

HAZARDOUS WASTE MANAGEMENT IN MANITOBA

Manitoba
Environment
and Workplace
Safety and Health

HAZARDOUS WASTE MANAGEMENT IN MANITOBA

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1. Introduction

This report is part of Phase 1 of a three-phase Action Plan announced by the Manitoba Minister of Environment in November, 1982 for development and implementation of an appropriate management system for the handling, treatment, and ultimate disposal of hazardous and special wastes generated within the province of Manitoba. It contains (i) an assessment of the magnitude of the problem, i.e. identification and quantification of the generated wastes; (ii) results of work aimed at interim solution of the disposal problem; (iii) a discussion of available technologies for handling hazardous wastes and their relevance to Manitoba's situation; and (iv) an outline of the various options for dealing with the problem. Information presented in this report forms the basis for further public consultation and final selection of a preferred concept.

What is Hazardous Waste

Wastes are inevitable byproducts of all life. In general, all wastes could in some degree harm the organisms that produced them, and the organisms develop various ways to deal with their wastes. Humans produce rather an inordinate amount and diversity of waste, and the term hazardous waste has taken on a special meaning: it designates those substances or materials which, by their nature, have the greatest potential to cause damage to either human health or the environment.

In practice, hazardous wastes include a wide range of materials, from familiar ones, such as remnants of household pesticides or drain cleaners to more esoteric compounds used by some manufacturing industries, or to biological byproducts from hospitals or laboratories.

The Dangerous Goods Handling and Transportation Act proclaimed by the Government of Manitoba in August, 1984 legally defines hazardous waste as "any substance or group of substances so designated by the regulations or conforming to criteria set out in regulations." Upcoming regulations shall define both precise criteria and specific substances for designating certain goods or products as hazardous waste. For the purpose of this report, "substance" is defined in Section 2.

Two examples

1. Arsenical compounds were formerly widely used to combat various agricultural pests. Due to their toxicity, these pesticides were slowly phased out and are nowadays used only under very specific conditions. Investigations by provincial Environment authorities discovered arsenic contamination in the soil, vegetation, and vegetables grown in the neighborhood of a warehouse full of arsenic trioxide which had been left, unused and inadequately contained for a number of years. The situation necessitated long negotiations before a place was found where the compound could be safely handled, and expensive removal and transport procedures had to be followed.

2. In January, 1982 a train derailment at Austin, Manitoba, resulted in a spill of 30,000 litres of alkaline materials: sodium sulfate, destined originally to a chemical manufacturer, and some quantity of liquid drain cleaner. Although the emergency response personnel arrived within hours of the accident, and although the spill was contained within days, it took until April to complete disposal of the contaminated material.

These two real-life stories are recalled here to demonstrate two points: One — many substances can become hazardous waste when not used in a proper way, or when released to the environment as a result of an accident; and Two — without a system for disposal of the hazardous wastes it may take unacceptably long time or unnecessarily costly efforts to finally dispose of them in a safe manner. In addition, every delay increases the potential for further accidents or problems.

The Present Situation

Many hazardous wastes are, unfortunately, treated like everyday garbage because, without special facilities for collection, transport, handling, or disposal, there are few alternatives. The Environment department handles the disposal of small quantities of waste for industry, hospitals, schools, etc., but most companies are left to dispose of their own waste. Some wastes are stored at the department's interim storage facility at Gimli, often to be shipped for disposal at hazardous waste treatment facilities outside Manitoba. Some wastes are safely disposed of in the Province by the department. In many cases the department can only respond to emergency-type situations. Even so, the Emergency Response Team was called upon 267 times during 1984. The team was involved in the cleanup of 82 petroleum spills.

It is estimated that 350,000 to 500,000 chemical pesticide containers are disposed of in Manitoba each year [29][1]. These containers most often end up in local waste disposal grounds. With the help of the federal and provincial Governments the rural municipalities have embarked on programs for can crushing and liquid pesticide residue collection. The liquid residue is shipped for disposal out of the province.

There is no Manitoba facility capable of properly treating and disposing of many of the waste materials currently deposited in waste disposal grounds. Without a management

[1] Numbers in square brackets refer to Literature Cited, pages 54-55.

system, the hazards of these wastes are higher than necessary because of uncontrolled disposal in municipal landfills and elsewhere, but the present disposal system is not adequately equipped for handling of all the generated hazardous wastes.

The Action Plan

In response to these concerns the Minister announced, in November, 1982, a comprehensive Action Plan for development and implementation of an appropriate management system for the handling, treatment, and ultimate disposal of hazardous and special wastes generated within the province.

Phase One of the Plan was launched with a public symposium on hazardous and special wastes [18], followed by information meetings held in many communities throughout the province to increase public awareness of the problem and to solicit public input, and finally by public hearings on management system needs and criteria [7]. In conjunction with these activities, enabling legislation was introduced in the legislative assembly, and in August, 1984 The Dangerous Goods Handling and Transportation Act was proclaimed. This Act gives the Department of Environment and Workplace Safety and Health a mandate to proceed with development of the appropriate regulations and with the development of a management system.

Another part of Phase One was the implementation of an "Information Exchange" involving the Environment department and the various Manitoba industries which are potential generators of hazardous wastes. The Information Exchange apprised the industries of the latest developments regarding legislation and the Government's program. The industries provided information on kinds and quantities of dangerous goods/hazardous wastes that they routinely handle (see Section 2).

Currently the basic legislation (The Dangerous Goods Handling and Transportation Act) is in place. Upon publication of this report further public consultations will take place, and after a preferred waste management concept option is selected (from those presented in Section 7), Phase two begins. In the second phase of the Action Plan information derived from the first phase will be applied to determine, again with appropriate public input, the necessary components of the selected option. Also, regulations under The Dangerous Goods Handling and Transportation Act will be developed. If a treatment facility is identified as part of the system, the site selection process will be initiated.

Phase Three will be characterized by phasing in, and finally, full implementation of the chosen hazardous waste management system, including the necessary monitoring and control.

2. Hazardous Waste Generated

This section identifies and quantifies hazardous wastes produced in the province, and the different types of industries that generate these wastes.

Methods

During 1983 and 1984 a Hazardous Waste Information Exchange was implemented throughout the province. With the assistance of the personnel of the Department of Environment and Workplace Safety and Health information was solicited from all major manufacturing firms.

Data in this report are based on the information provided voluntarily by the industries which participated in the Information Exchange, supplemented by file and other information on various other agencies including the provincial and municipal Governments. The companies were identified from the trade directory [22], "yellow pages," file records, etc. A conscious attempt was made to involve a representative sample of all the different industry types. When there was a choice, larger establishments were selected (usually 25+ employees), because these can be expected to generate most of the respective hazardous wastes [30].

In total, 712 establishments were approached, by letter and by telephone follow-up. Of those, 252 companies reported that they produced no hazardous waste, and 32 were no longer in business in Manitoba; only 17 refused to grant an interview. The results presented in this report are then based on personal interviews conducted with management personnel of 411 companies. Approximately 30 persons were involved in conducting the interviews, after brief initial training. Accordingly there were varying degrees of expertise which may have rendered some information less comprehensive.

The data were entered into, and sorted by a computer at Manitoba Data Systems. A manual check was then conducted on all data and apparent anomalies were corrected. For example, quantities of waste were checked against quantities of purchased raw materials and against volumes and numbers of empty containers. Disposal method was also checked to ensure it was appropriate to the component, and if necessary the data were reviewed with the respective company management. Information is presented broken down by general criteria, but the only company identification is by the broad categories of the Standard Industrial Classification (see below). The quantities were recorded in kilograms or litres generated per month, and are presented always in terms of tonnes per year. A litre of volume was considered equivalent to a kilogram of weight or mass in all calculations.

Definitions

In this report several words have specifically defined meanings; these definitions are strictly adhered to:

Class or **UN Class** refers to a group of substances with similar chemical properties. The classification was originally developed by the United Nations [40].

There are nine classes of dangerous goods [34]:

Class 1 — Explosives, including explosives within the meaning of the Explosives Act (Canada);

Class 2 — Gases: compressed, deeply refrigerated, liquefied or dissolved under pressure;

Class 3 — Flammable and combustible liquids;

Class 4 — Flammable solids; substances liable to spontaneous combustion; substances that on contact with water emit flammable gases;

Class 5 — Oxidizing substances; organic peroxides;

Class 6 — Poisonous (toxic) and infectious substances;

Class 7 — Radioactive materials and prescribed substances within the meaning of the Atomic Energy Control Act (Canada);

Class 8 — Corrosives;

Class 9 — Miscellaneous products; substances or organisms considered by the Governor in Council to be dangerous to life, health, property or the environment when handled, offered for transport or transported and prescribed to be included in this class.

In Canada, Class 1, Explosives, and Class 7, Radioactive materials are regulated under federal legislation, and therefore were not subject to the Information Exchange.

PIN or Product Identification Number. These numbers correspond to "UN numbers," derived originally by the United Nations [40] and to numbers used by North American regulatory agencies to designate various chemicals and other materials [10].

Region. Six regions were identified, corresponding to those used by the department's Public Health Inspection Services (Figure 1). Regional breakdown of the data is provided to identify those areas of the province where most of the hazardous wastes are generated.

SIC or SIC code refers to the Standard Industrial Classification code used in North America to categorize various industries according to their activities or goods handled and produced [9]. The SIC codes can consist of up to four digits, depending on the detail of the categorization. Two-digit codes which identify broad industrial categories are used in this report. The industrial categories together with their SIC codes are shown e.g. in Table 1.

Substance always means that which is identified by one specific Product Identification Number on the Dangerous Goods list prepared by the Government of Canada for use with the Transportation of Dangerous Goods Act, even though sometimes the same number may identify more than one chemical compound.

A substance by its nature can often be classified under more than one UN Class. In those cases the substance was always classified in our tables under its "primary" classification, i.e. the first class noted for it in the Transportation of Dangerous Goods Act regulations.

Results

The identified amount of hazardous waste generated within the province is 20,325 tonnes per year (Table 1), produced by at least 293 companies (Table 2). This quantity does not include air emissions and currently recycled

Figure 1 Hazardous waste regions

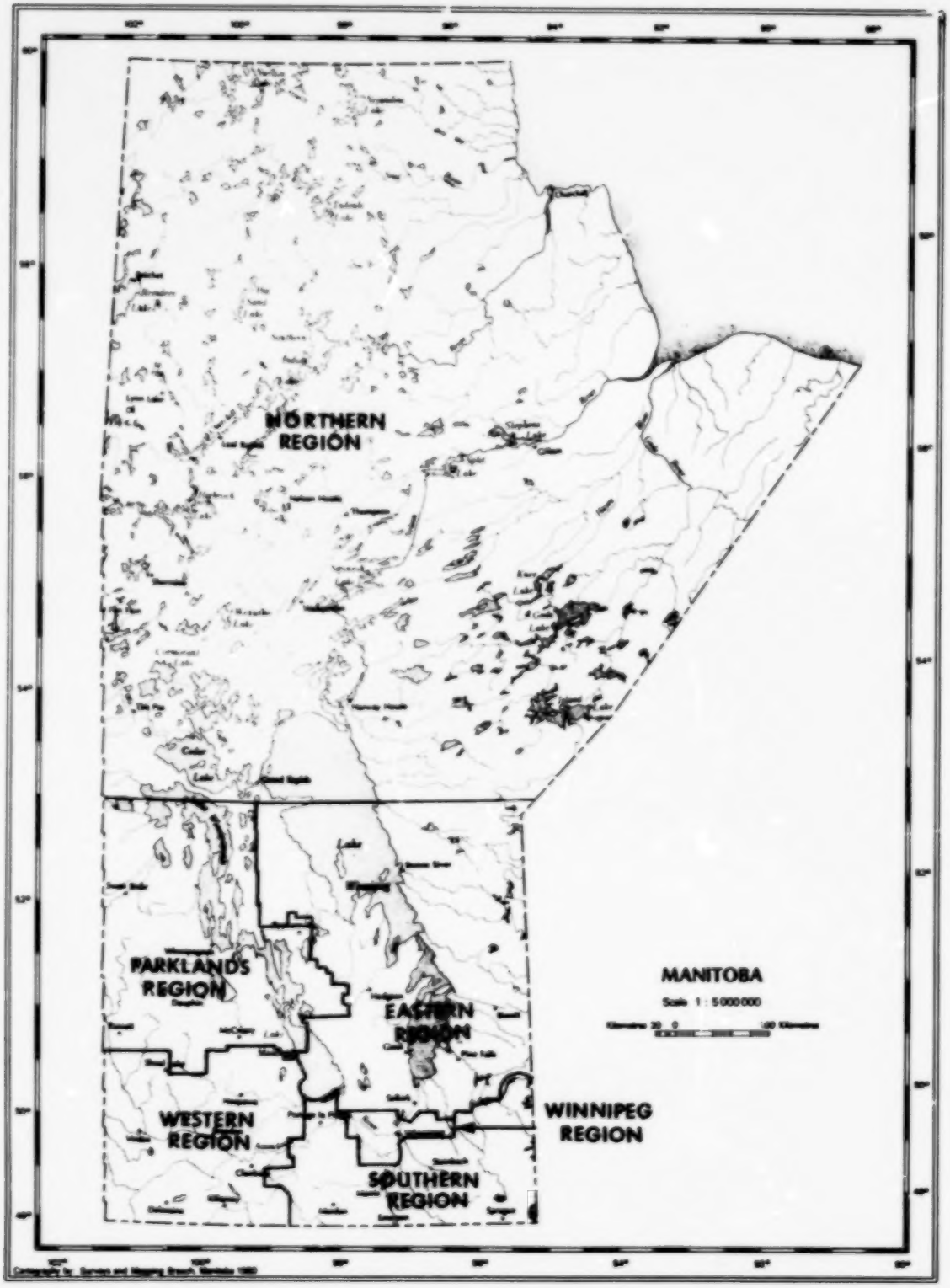


Table 1 Quantities of generated hazardous waste (tonnes/year) and method of treatment/disposal

SIC	Industry	Chemical/ Physical	Incineration	Landfilling	Land Spreading	Other	Sewering	Storage	Total	Percent	Cumulative Percent
28	Chemicals	1	0	2115	2	3950	994	0	7062	35	35
26	Paper products	0	0	0	0	0	4429	0	4429	22	57
10	Metal mining	0	397	5	4	443	1649	0	2498	12	69
20	Food products	0	2	6	17	0	2397	0	2422	12	81
76	Repair serv.	0	0	1092	3	1	0	0	1096	5	87
31	Leather	0	0	0	0	364	295	0	658	3	90
14	Quarrying	0	0	491	0	0	0	0	491	2	92
33	Primary metal	0	0	296	0	0	1	108	405	2	94
27	Printing	0	0	24	0	10	264	11	309	2	96
39	Mfg., Miscellan.	0	0	57	0	0	213	0	270	1	97
35	Machinery, non-el.	0	1	95	0	1	42	0	139	1	98
75	Auto repair	0	0	12	0	108	11	0	131	1	98
34	Fabricated metal	0	0	5	3	54	47	0	109	1	99
37	Transport. equip.	0	13	35	0	1	14	2	65	0	99
36	Electrial mach.	0	0	12	0	0	36	0	48	0	99
30	Rubber, plastics	0	0	25	0	8	12	0	44	0	100
50	Whsl., durab. goods	0	0	0	0	0	23	0	23	0	100
15	Building constr.	0	0	0	14	0	0	0	14	0	100
32	Stone, clay, concrete	0	0	0	0	0	1	10	11	0	100
25	Furniture	0	0	0	0	0	7	0	7	0	100
23	Apparel	0	0	0	0	0	1	0	1	0	100
24	Lumber products	0	0	1	0	0	0	0	1	0	100
73	Business services	0	0	0	0	0	1	0	1	0	100
17	Construction trade	0	0	0	0	0	1	0	1	0	100
29	Petrol refining	0	0	0	0	0	0	0	0	0	100
07	Agricult. services	0	0	0	0	0	0	0	0	0	100
Total		2	413	4270	44	4939	10435	131	20235	100	
Percent		0	2	21	0	24	52	1	100		

[1] includes painting, printing, scrubbing, smelting, solidification, welding, and "unconfirmed"

Table 2 Regional breakdown of generated quantities (tonnes/year)

SIC	Industry	Eastern	Northern	Parkland	Southern	Western	Winnipeg	TOTAL
28	Chemicals	0	0	0	0	4927	2135	7062
26	Paper products	4404	3	0	0	0	21	4429
10	Metal mining	0	2498	0	0	0	0	2498
20	Food products	207	0	0	40	41	2134	2422
76	Repair service	0	0	0	4	0	1092	1096
31	Leather	0	0	0	0	0	658	658
14	Quarrying	0	0	0	0	0	491	491
33	Primary metal	1	108	0	0	0	296	405
27	Printing	0	4	2	6	3	294	309
39	Mfg. miscellan.	0	0	0	0	0	270	270
35	Machinery, non-el.	0	0	0	22	3	114	139
75	Auto repair	0	13	0	2	1	115	131
34	Fabricated metal	0	0	0	2	3	104	109
37	Transport. equip.	0	0	0	46	0	18	65
36	Electrical mach.	0	0	0	0	0	48	48
30	Rubber, plastics	0	0	0	5	7	32	44
50	Whlsl., durab. goods	0	0	0	0	0	23	23
15	Building constr.	0	0	0	0	0	14	14
32	Stone, clay, concrete	0	0	0	0	0	11	11
25	Furniture	0	0	0	0	0	7	7
23	Apparel	0	0	0	0	0	1	1
24	Lumber products	0	0	0	0	0	0	1
73	Business services	0	0	0	0	0	1	1
17	Construction trade	0	0	0	0	0	1	1
29	Petrol refining	0	0	0	0	0	0	0
07	Agricult. services	0	0	0	0	0	0	
Totals		4612	2626	2	129	4985	7881	20235
Percent		23	13	0	1	25	39	100

wastes. The generators (companies) belong to 26 different Standard Industrial Classification (SIC) groups. Table 1 also shows the methods of treatment/disposal which the wastes receive (Figure 4b). The greatest quantity of waste is being sewered or deposited in landfills. The category "other" (24% of the hazardous waste) includes several different treatments (Table 1 footnote) each accounting for a rather small percentage of total waste. The chemical and paper products industries together account for 57% of the generated hazardous waste, followed by the metal mining and food products industries.

Regionally, most of the hazardous waste is being generated in the Winnipeg region (39%), followed by the Western, Eastern and Northern regions (Figure 2, Table 2). The distribution of the waste-generating industries is shown in Table 3. The Winnipeg region has the highest number of companies (186), Parkland region the lowest (3), but the ranking of the remaining regions is not identical to their ranking by generated quantities (Table 3).

There were 142 hazardous waste substances identified by the information exchange (Table 4). Forty two of them (30%) are generated by the chemical industry; the other largest generators are the printing, fabricated metal, and food products industries (Figure 3, Table 5). Regional breakdown of the numbers of substances is shown in Table 6. Winnipeg and Western regions produce the greatest variety of substances.

Figure 2. Proportion of hazardous waste generated in each region by the main five industry groups. Air emissions and recycled wastes are excluded.

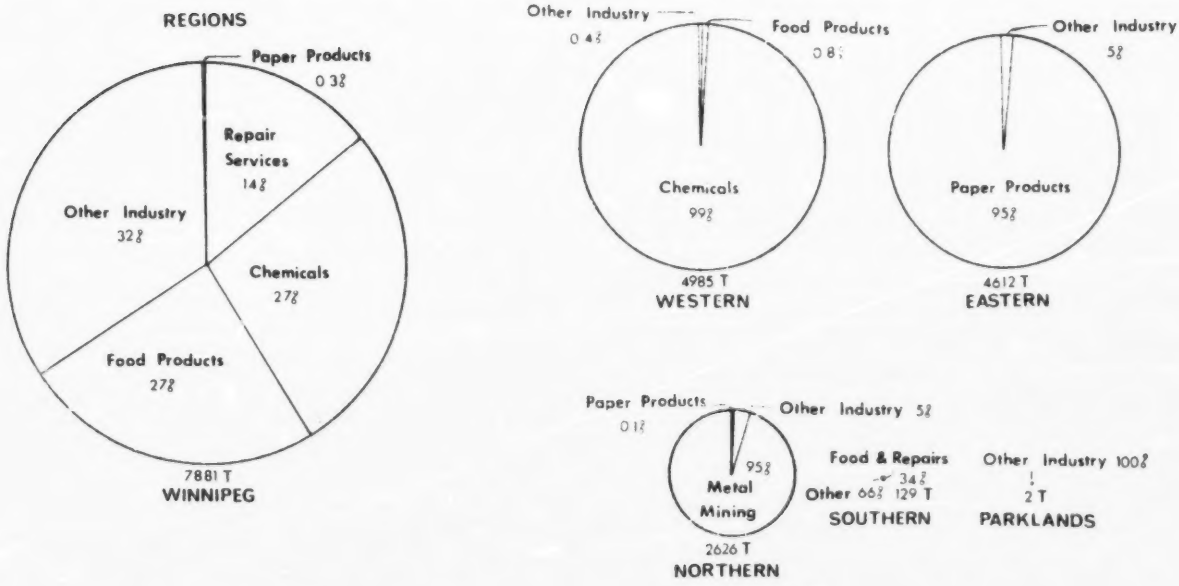


Table 3 Numbers of companies generating hazardous waste, by region

SIC	Industry	Eastern	Northern	Parkland	Southern	Western	Winnipeg	TOTAL	Percent
27	Printing	2	3	3	6	17	64	94	32.4
34	Fabricated metal	0	1	0	9	11	21	42	14.3
35	Machinery, non-el.	0	0	0	4	2	22	28	9.6
28	Chemicals	0	0	0	1	2	13	16	5.5
37	Transport. equip.	0	0	0	5	0	8	13	4.4
75	Auto repair	0	7	0	1	1	4	13	4.4
20	Food products	1	0	0	1	2	7	11	3.8
76	Repair serv.	0	4	0	4	0	3	11	3.8
30	Rubber, plastics	0	0	0	2	2	6	10	3.4
39	Mfg., miscellan.	0	0	0	1	3	6	10	3.4
33	Primary metal	1	1	0	1	0	6	9	3.1
36	Electrical mach.	0	0	0	0	0	7	7	2.4
25	Furniture	0	0	0	0	1	5	6	2.0
24	Lumber products	0	0	0	2	1	1	4	1.4
26	Paper products	1	1	0	0	0	2	4	1.4
32	Stone, clay, concrete	1	0	0	0	0	2	3	1.0
31	Leather	0	0	0	0	0	2	2	.7
07	Agricult. services	0	0	0	0	1	0	1	.3
10	Metal mining	0	1	0	0	0	0	1	.3
14	Quarrying	0	0	0	0	0	1	2	.3
15	Building constr.	0	0	0	0	0	1	1	.3
17	Construction trade	0	0	0	0	0	1	1	.3
23	Apparel	0	0	0	0	0	1	1	.3
29	Petrol refining	0	0	0	0	0	1	1	.3
50	Whlsl., durab. goods	0	0	0	0	0	1	1	.3
73	Business services	0	0	0	0	0	1	1	.3
Total		6	18	3	37	43	186	293	100.0
Percent		2	6	1	13	15	64	100	

Table 4 Identified hazardous waste substances

PIN	Substance	Quantity Produced (tonnes yr)	Rank[1]
2789	Acetic acid, glacial or acetic solution	< 1	
1090	Acetone	19	
1001	Acetylene, dissolved	< 1	
1986	Alcohols, toxic, N.O.S.*	*8	
2761	Aldrin	< 1	
1760	Aluminum phosphate	88	
9078	Aluminum sulphate	184	
2672	Ammonia solutions or ammonium hydroxide	< 1	
1005	Ammonia, anhydrous	194	
9085	Ammonium chloride	37	
2072	Ammonium nitrate fertilizers, N.O.S.	< 1	
9190	Ammonium permanganate	1	
1477	Ammonium sulphate nitrate	1	
9092	Ammonium thiocyanate	< 1	
9093	Ammonium thiosulphate	< 1	
1599	Antimony compound, inorganic, N.O.S.	1	
1325	**Antimony sulphide**	**563**	**7**
1559	Arsenic pentoxide	< 1	
1400	Barium	< 1	
2570	Cadmium acetate	< 1	
1748	Calcium hypochlorite	2	
1719	Caustic alkali liquids, N.O.S.	35	
2000	Celluloid	1	
1361	Charcoal or carbon	9	
1362	Charcoal, activated or carbon, activated	1	
1017	Chlorine	69	
1463	Chromic acid	214	
9100	Chromic sulphate	2	
1587	Copper cyanide	< 1	
2920	Corrosive liquids, flammable, N.O.S.	69	
1760	**Corrosive solids, N.O.S.**	**2542**	**3**
2923	Corrosive solids, poisonous, N.O.S.	< 1	
1479	Cupric nitrate	< 1	
1588	Cyanides, inorganic, N.O.S.	< 1	
2996	Dichlone	< 1	
1593	Dichloromethane or methylene chloride	< 1	
2262	Dimethylcarbamoyl chloride	< 1	
2801	Dyes, N.O.S. or dye Intermediates, corrosive	< 1	
1602	Dyes, N.O.S. or Dye intermediates, N.O.S., poisonous	< 1	
1850	Eradicators, paint or grease, liquid	14	
1170	Ethanol or ethyl alcohol or ethanol solution	< 1	
1962	Ethylene	72	
9117	Ethylenediaminetetraacetic acid or EDTA	< 1	
1169	Extracts, aromatic, liquid	< 1	
9125	Ferrous sulphate	35	
1324	Films, nitrocellulose base	< 1	
1142	Flammable liquid preparations, N.O.S.	50	
1993	Flammable liquids, N.O.S.	270	
1992	Flammable liquids, poisonous, N.O.S.	3	
2926	Flammable solids, poisonous, N.O.S.	< 1	
2209	Formaldehyde	2	
1779	Formic acid	< 1	
1610	Halogenated irritating liquids, N.O.S.	2	
9037	Hexachloroethane	< 1	
1789	Hydrochloric acid solution	276	
1790	Hydrofluoric acid solution	< 1	
2984	Hydrogen peroxide	< 1	
1791	Hypochlorite solutions	264	
1210	Ink, printer's, flash pt. <37.8 C.	4	
1376	Iron oxide	< 1	
2478	Isocyanates, N.O.S., or isocyanate solutions	< 1	
1219	Isopropanol or isopropyl alcohol	2	
1223	Kerosene	< 1	
1224	Ketones, liquid, N.O.S.	< 1	
1794	Lead dross	< 1	
2811	**Lead fluoride**	**339**	**10**
1869	Magnesium	1	
1851	Medicines, N.O.S.	< 1	
1228	Mercaptans, liquid, N.O.S. or Mercaptan mixt	< 1	
1624	Mercuric chloride	< 1	
2024	Mercury compounds, liquid, N.O.S.	< 1	
1230	Methanol or methyl alcohol	1	
2563	Methyl ethyl ketone peroxide(s)	< 1	
2553	Naphtha (mixture)	< 1	
1255	**Naphtha, petroleum**	**1091**	**5**
1256	Naphtha, solvent	1	
2881	Nickel catalyst	< 1	
9139	Nickel chloride	< 1	
9141	Nickel sulphate	1	
2031	Nitric acid	< 1	
1261	Nitromethane	< 1	
9193	Oxidizer, liquid, corrosive, N.O.S.	< 1	
9193	Oxidizer, solid, corrosive, N.O.S.	3	
1072	Oxygen, compressed	< 1	
1263	Paints, enamels, lacquers, stains, shellac	120	
1267	Petroleum crude oil	< 1	
1268	**Petroleum distillates, N.O.S.**	**554**	**8**
1270	**Petroleum oil**	**723**	**6**
1271	Petroleum spirit	< 1	
1671	Phenol, solid	< 1	
2337	Phenyl mercaptan	< 1	
1673	Phenylenediamines (M- P-)	1	
1805	Phosphoric acid	22	
1338	Phosphorous, amorphous	< 1	
2927	Poisonous liquids, corrosive, N.O.S.	< 1	
2929	**Poisonous liquids, flammable N.O.S.**	**496**	**9**
2810	Poisonous liquids, N.O.S.	26	
2928	Poisonous solids, corrosive, N.O.S.	< 1	
2930	Poisonous solids, flammable, N.O.S.	40	
2315	Polychlorinated biphenyls	108	
2211	Polystyrene beads, expandable	< 1	
1680	Potassium cyanide	< 1	
1813	Potassium hydroxide, solid or solution	< 1	
2033	Potassium oxide	< 1	
1978	Propane	< 1	
1856	Rags, oily	3	
1979	Rare gases mixtures	< 1	
1866	Resin solution, flammable	1	
1896	Resin solution, poisonous	22	
1286	Rosin oil	< 1	
1287	Rubber solution	1	
1906	Sludge acid	< 1	
1907	Soda lime with more than 4% sodium hydroxide	35	
1496	Sodium chlorite	1	
1689	Sodium cyanide	3	
1690	Sodium fluoride	< 1	
2318	Sodium hydrosulphide, with less than 25% water	< 1	
1823	**Sodium hydroxide**	**5504**	**1**
1498	Sodium nitrate	1	
1500	Sodium nitrite	1	
9147	Sodium phosphate, dibasic	1	
1385	Sodium sulphide, anhydrous	< 1	
1827	**Stannic chloride**	**3600**	**2**
2967	Sulphamic acid	1	
1350	Sulphur	< 1	
1830	**Sulphuric acid**	**2167**	**4**
1999	Tars, liquid, including road asphalt and oil	1	
1897	Tetrachloroethylene	< 1	
1707	Thallium compounds, N.O.S.	1	
2727	Thallium nitrate	< 1	
1294	Toluene	17	
1710	Trichloroethylene	2	
1300	Turpentine substitute	293	
1301	Vinyl acetate, inhibited	< 1	
9301	Waste type 1	< 1	
9311	Waste type 11	< 1	
2590	White asbestos	< 1	
1307	Xylenes	3	
1713	Zinc cyanide	1	
1436	Zinc powder or zinc dust	< 1	
1932	Zirconium, scrap	2	
2831	1,1,1-trichloroethane	6	

Total: 147 substances

* N.O.S. = not otherwise specified

[1] The 10 substances produced in largest quantities are in bold print and ranked by quantity.

Table 5: Number of hazardous waste substances generated by industries

SIC	Industry	No. of Substances	% of total[1]	SIC	Industry	No. of Substances	% of total[1]
28	Chemicals	47	34.3	76	Repair service	9	6.6
27	Printing	42	30.7	25	Furniture	8	5.8
34	Fabricated metal	38	27.7	10	Metal mining	6	4.4
20	Food products	22	16.1	24	Lumber products	5	3.6
35	Machinery, non-el.	21	15.3	26	Paper products	5	3.6
37	Transport equip.	21	15.3	23	Apparel	3	2.2
36	Electrical mach.	19	13.9	29	Petrol refining	2	1.5
39	Mfg., miscellan.	17	12.4	50	Whlsl., durab. goods	2	1.5
31	Leather	15	10.9	07	Agricult. services	1	.7
30	Rubber, plastics	14	10.2	14	Quarrying	1	.7
75	Auto repair	14	10.2	15	Building constr.	1	.7
33	Primary metal	13	9.5	17	Construction trade	1	.7
32	Stone, clay, concrete	11	8.0	73	Business services	1	.7
	TOTAL SUBSTANCES GENERATED:				142		

[1]Percentages do not total 100, because different industries may generate the same substances

Table 6: Number of substances generated, by region

SIC	Industry	Eastern	Northern	Parkland	Southern	Western	Winnipeg
27	Printing	2	14	3	9	11	35
28	Chemicals	8	0	0	3	25	26
34	Fabricated metal	1	2	0	9	7	35
20	Food products	0	0	0	8	8	16
35	Machinery, non-el.	0	0	0	4	3	19
37	Transport. equip.	0	0	0	5	0	19
75	Auto repair	0	5	0	4	2	10
30	Rubber, plastics	0	0	0	2	8	9
36	Electrical mach.	0	0	0	0	0	19
33	Primary metal	2	3	0	1	0	10
76	Repair serv.	0	5	0	5	0	6
31	Leather	0	0	0	0	0	15
39	Mfg., miscellan.	0	0	0	1	4	10
32	Stone, clay, concrete	0	0	0	0	0	9
25	Furniture	0	0	0	0	1	7
23	Apparel	4	0	0	0	0	3
10	Metal mining	0	6	0	0	0	0
26	Paper products	0	2	0	0	0	4
24	Lumber products	0	0	0	2	2	1
29	Petrol. refining	0	0	0	0	0	2
50	Whlsl., durab. goods	0	0	0	0	0	2
07	Agricult. services	0	0	0	0	1	0
14	Quarrying	0	0	0	0	0	1
15	Building constr.	0	0	0	0	0	1
17	Construction trade	0	0	0	0	0	1
73	Business services	0	0	0	0	0	1
	Regional totals[1]	13	31	3	31	46	104
	Total 142 substances						

[1]Columns do not add up to the regional totals because different industries may produce identical substances. Regional totals do not add up to the overall total because identical substances may be generated in different regions.

Of the 20,235 tonnes per year of hazardous wastes, the primary classification of 74 percent is corrosives (class 8), 16 percent are flammable liquids (Class 3). The remaining five classes account for only 10 percent of the total (Figure 4a, Table 7).

Table 8 provides a breakdown by class and region of the generated quantities. The greatest quantities for most classes appear in the Winnipeg and Western regions. The number of substances per class in each region is shown in Table 9. The Winnipeg region again has the greatest number of substances in most classes.

The diagram in Figure 5 illustrates both quantities and numbers of generated substances for each industrial group.

Table 7: Breakdown of generated quantities (tonnes/year) by class.

SIC	Industry	Class							TOTAL
		2 Comp. Gases	3 Flam. Liquids	4 Flam. Solids	5 Oxidizers	6 Toxics	8 Corrosives	9 Other	
28	Chemicals	263	14	2	3	15	6764	3	7062
26	Paper products	0	4	0	0	0	4425	0	4429
10	Metal mining	0	6	2	0	534	1955	0	2498
20	Food products	0	1082	0	5	0	1334	0	2422
28	Repair serv.	0	1096	0	0	0	0	0	1096
31	Leather	0	29	335	0	0	37	257	658
14	Quarrying	0	491	0	0	0	0	0	491
33	Primary metal	0	3	9	0	0	284	108	405
27	Printing	0	46	223	0	0	38	2	309
39	Mfg., Miscellan.	0	36	0	209	0	19	5	270
35	Machinery, non-el.	0	124	0	1	0	14	0	139
75	Auto repair	72	59	1	0	0	0	0	131
34	Fabricated metal	0	60	1	2	12	30	4	109
37	Transport. equip.	0	62	2	0	0	0	0	65
36	Electrical mach.	0	6	1	0	4	36	3	48
30	Rubber, plastics	0	14	3	0	27	0	0	44
50	Whlsl., durab. goods	0	23	0	0	0	0	0	23
15	Building constr.	0	14	0	0	0	0	0	14
32	Stone, clay, concrete	0	10	0	0	0	1	0	11
25	Furniture	0	0	0	3	0	3	0	7
23	Apparel	0	1	0	0	0	0	0	1
24	Lumber products	0	0	0	0	0	0	0	1
73	Business services	0	0	0	0	0	1	0	1
17	Construction trade	0	0	0	0	0	1	0	1
29	Petrol refining	0	0	0	0	0	0	0	0
7	Agricult. services	0	0	0	0	0	0	0	0
Totals		335	3180	580	223	593	14942	382	20235
Perc.		2	16	3	1	3	74	2	100

1: UN Class 1, Explosives and Class 7, Radioactives are covered by Federal Regulations.

Figure 3. Proportion of the total number of hazardous waste substances generated by different industries

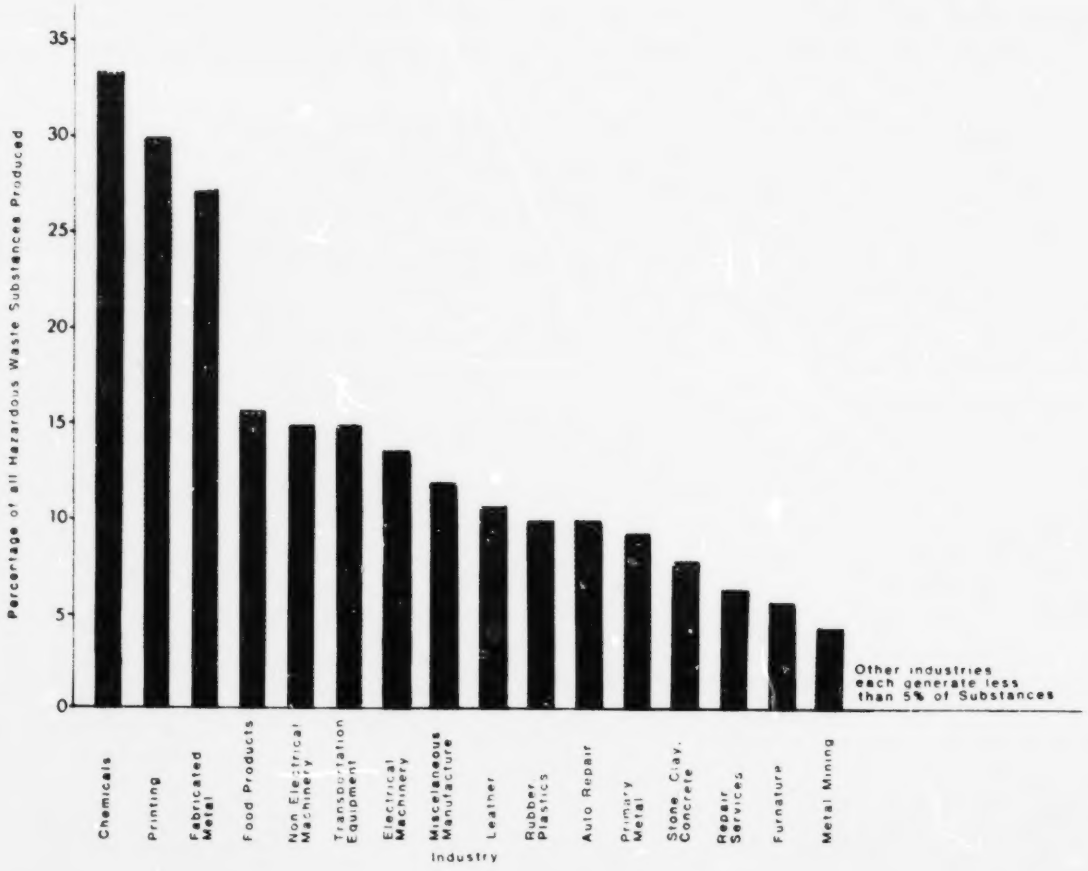


Figure 4a. Proportion of waste generated per hazardous waste class (excluding air emissions, recycled waste, and classes 1 and 7 (explosive and radioactive)

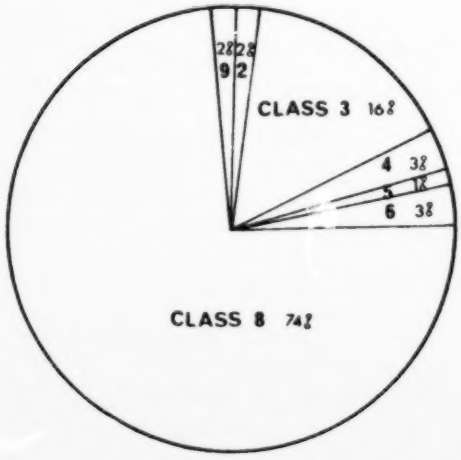


Figure 4b. Proportion of treatment and disposal methods used for hazardous waste (air emissions and recycling excluded)

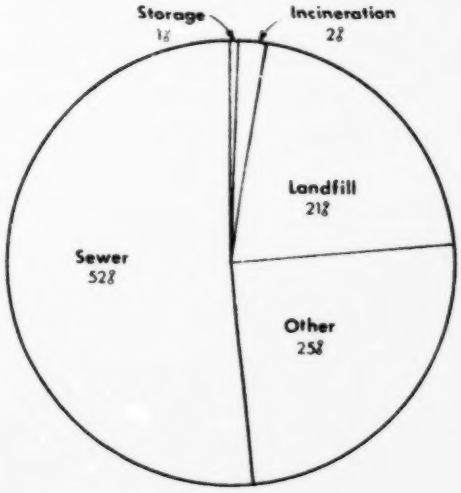


Table 8: Quantities generated per class (tonnes/year), by region

Class[1]	Eastern	Northern	Parkland	Southern	Western	Winnipeg	Total	Percent
2 Comp. gases	0	0	0	0	263	72	335	2
3 Flam. liquids	6	20	0	124	10	3019	3180	16
4 Flam. solids	0	3	0	0	2	574	580	3
5 Oxidizers	0	0	0	0	5	219	223	1
6 Toxics	0	534	0	0	6	52	593	3
8 Corrosives	406	1961	1	4	4699	3672	14942	74
9 Other	0	108	0	0	2	272	382	2
Total	4612	2626	2	129	4985	7881	20235	100
Perc.	23	13	0	1	25	39	100	

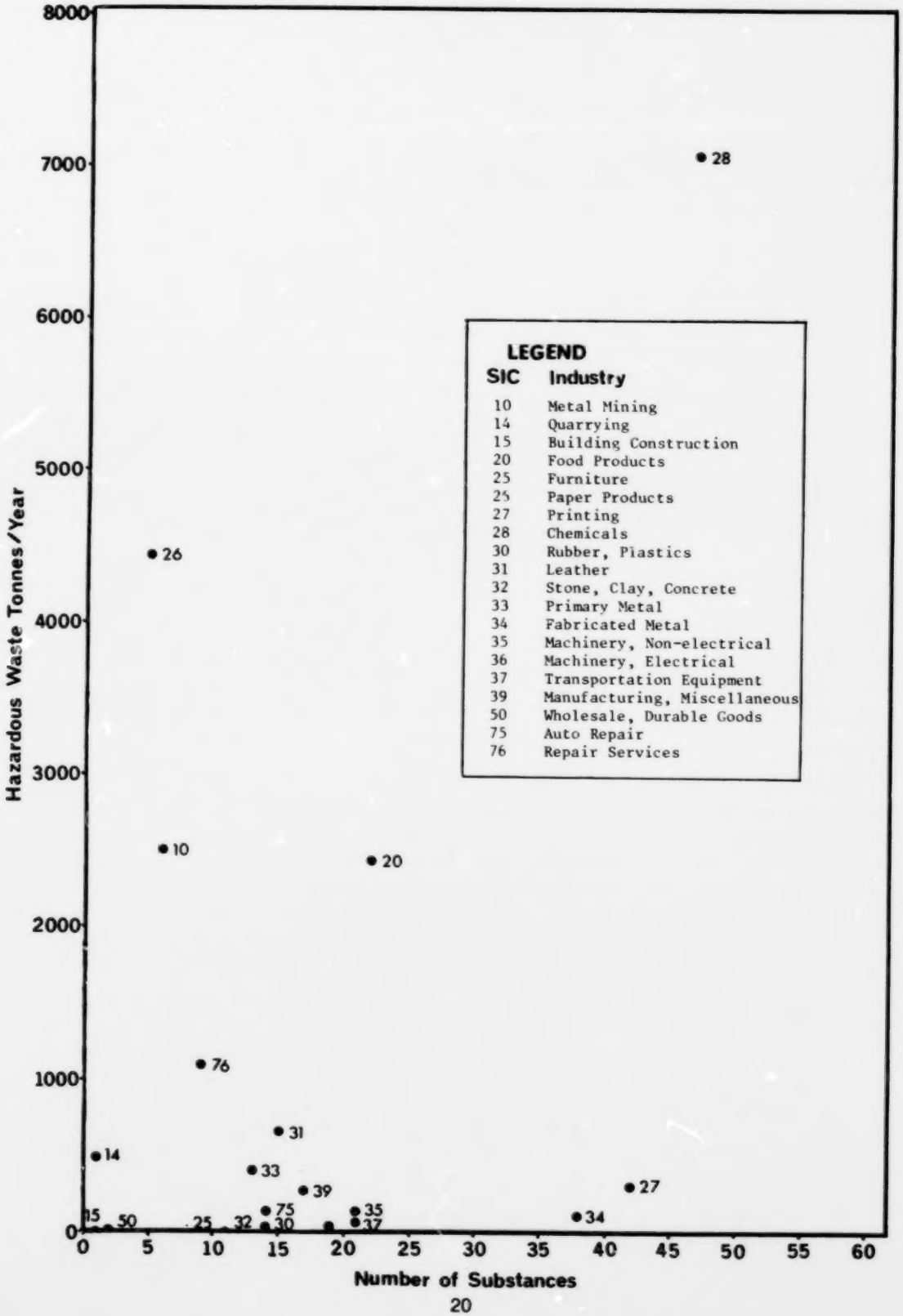
[1]: UN Class 1, Explosives and Class 7, Radioactives are covered by Federal Regulations.

Table 9: Number of substances generated per class, by region.

Class[1]	Eastern	Northern	Parkland	Southern	Western	Winnipeg
2 Comp. gases	0	3	0	1	3	2
3 Flam. liquids	4	12	2	13	12	29
4 Flam. solids	1	3	0	3	4	14
5 Oxidizers	0	0	0	2	7	7
6 Toxics	3	3	0	4	4	20
8 Corrosives	5	7	1	7	11	17
9 Other	0	3	0	1	5	19
Total	13	31	3	31	46	108
Overall total[2] = 142 substances						

[1]: UN Class 1, Explosives and Class 7, Radioactives are covered by Federal Regulations.
[2]: Regional totals do not add up to the overall total because identical substances may be generated in different regions.

Figure 5. Quantity and number of hazardous waste substances generated by different industries (excluding air emissions and recycled waste, and omitting those which generate 1 tonne/year or less)



Discussion

In the Results section, the tables intentionally do not include those hazardous wastes which, although identified by the information exchange program, are either recycled or released to the atmosphere. That is appropriate because recycled substances normally would not require handling by any future system, and atmospheric releases are currently not amenable to the system. Atmospheric releases of pollutants are provincially regulated under The Clean Environment Act.

This report puts the greatest emphasis on the industrially generated hazardous waste, and thus may be omitting, of necessity, some of the wastes generated from other sources. Discarded pesticide containers are one such source [29]. Assuming 80 ml of the pesticide residue remaining in the "empty" can, up to 40 tonnes per year of pesticides may be so discarded, and will have to be handled by the future waste management system.

Another category of potentially hazardous waste which was not covered by the Information Exchange are discarded medications. For example, during a two-week Medicine Cabinet Clean-up campaign in 1979 the Manitoba Pharmaceutical Association disposed of 56,802 doses of drugs, vitamins and other medications [1]. Although the total quantity (less then 0.01 tonne) is insignificant, some medicines are highly toxic and would require special attention.

Many additional substances had to find a way to a safe disposal within the province, even though they may not be *sensu stricto* 'generated' here. During the past 5 years Waste Management Section personnel have collected, identified, and disposed of 1538 chemical compounds or formulations (Table 10). This involved usually very small quantities, such as old chemicals from school laboratories. The number is somewhat misleadingly large — the records didn't allow complete identification of duplications, e.g. of different formulations or concentrations of the same substance. All the same, it indicates that many unusual substances could be encountered, in addition to the 142 (Table 4) which comprise the bulk of the generated waste.

As a matter of general interest, Table 11 shows the quantities of all generated wastes, including among the treatments recycling and releases to the atmosphere. While recycling accounts for a relatively small percentage of the provincial hazardous waste, the air emissions, if included, would boost the total quantity to 51,200 tonnes per year. This figure is significant in helping to explain some of the differences between estimates of the quantity of hazardous wastes generated in Manitoba. It must be kept in mind that we are dealing with a dynamic process, where both quantities and substances will change in response to the changing technologies, economic conditions, public attitudes, and government regulations. For example, better separation of particulates from air emissions may in fact increase the quantities of hazardous waste to be handled by the system. On the other hand, more recycling would result in a decrease in the total amount.

Best known of the recent estimates is by Reid, Crowther & Partners [30]. Their estimate of total Manitoba production of hazardous waste is 42,000 tonnes per year. In the same study figures are given on *per capita* hazardous waste generation from various parts of the western world. Those estimates vary from 12 to 28 kg/person/year, however, they exclude alkalis, acids and some oil. With Manitoba's population of 1,050,000 people, between 12,600 and 29,400 tonnes per year could be thus

Table 10: Chemicals disposed of by Waste Management Section, 1980-1984

Location or Source	Number Handled	Disposal			
		Landfilled	Reacted	Detonated	Stored[1]
1. Universities	539	38	327		174
2. Public & Private Schools	312	22	140	72	78
3. Medical College	212	102	90		20
4. Laboratories	161	13	47	23	78
5. Canadian Department of Agriculture	76	1	2	52	21
6. Private Companies	49	2	24		23
7. Canadian Grain Commission	48	1	22	2	23
8. Provincial Government Departments	45		9	1	35
9. Hospitals	30	3	26		1
10. Community Colleges	24		13	8	3
11. Canadian Forces Bases	22	7	11	3	1
12. Private Citizens	20	1	2	3	14

[1]. Interim storage at Gimli

Table 11: Quantities of generated hazardous waste (tonnes/year) and method of treatment/disposal, including air emissions and recycled wastes[1]

SIC	Industry	Atmospheric Release	Chemical	Incineration	Landfilling	Land Spreading	Other	Recycling	Sewering	Storage	TOTAL	Percent
10	Metal mining	25716	0	397	5	5	443	0	1649	0	28214	55
28	Chemicals	2957	1	0	2115	2	3950	886	994	0	10905	21
26	Paper products	172	0	0	0	0	0	0	4429	0	4601	9
20	Food products	5	0	2	6	17	0	0	2397	0	2426	5
76	Repair ser.	1	0	0	1092	3	1	1	0	0	1097	2
31	Leather	0	0	0	0	0	364	0	295	0	658	1
33	Primary metal	0	0	0	296	0	0	124	1	108	529	1
14	Quarrying	0	0	0	491	0	0	0	0	0	491	1
36	Electrical mach.	1	0	0	12	0	0	408	36	0	457	1
27	Printing	48	0	0	24	0	10	70	264	11	428	1
30	Rubber, plastics	160	0	0	25	0	8	220	12	0	424	1
35	Machinery, non-el.	6	0	1	95	0	1	138	42	0	283	1
39	Mfg., miscellaneous	0	0	0	57	0	0	0	213	0	270	1
75	Auto repair	0	0	0	12	0	108	0	11	0	132	0
34	Fabricated metal	1	0	0	5	3	54	5	47	0	115	0
37	Transport. equip.	0	0	13	35	0	1	0	14	2	65	0
16	Non-build. constr.	0	0	0	0	0	0	54	0	0	54	0
29	Petrol. refining	0	0	0	0	0	0	24	0	0	24	0
55	Auto dealers	0	0	0	0	0	0	24	0	0	24	0
50	Whlsl., durab. goods	0	0	0	0	0	0	0	23	0	23	0
15	Building constr.	0	0	0	0	14	0	0	0	0	14	0
32	Stone, clay, concrete	3	0	0	0	0	0	0	1	10	13	0
25	Furniture	0	0	0	0	0	0	0	7	0	7	0
17	Construction trade	1	0	0	0	0	0	0	1	0	2	0
23	Apparel	0	0	0	0	0	0	0	1	0	2	0
24	Lumber products	0	0	0	0	0	0	0	0	0	1	0
73	Business services	0	0	0	0	0	0	0	1	0	1	0
07	Agricult. services	0	0	0	0	0	0	0	0	0	0	0
Total		29072	2	413	4270	44	4939	1955	10435	131	51261	100
Percent		57	0	1	8	0	10	4	20	0	100	

[1]: This is the only table which includes wastes either recycled or released to the atmosphere.

[2]: Includes painting, printing, scrubbing, smelting, solidification, welding and "unconfirmed."

expected. Our figures compare well with this range.

A United States federal study [41] focused on the production of hazardous wastes by various industry types. The author estimated that 47% of the hazardous waste is usually generated by a few major industries, in the case of his study mainly the chemical, petroleum, and rubber industries. The same situation is generally true for Manitoba although different industry groups are involved and the division is not quite as clear-cut. This is mostly due to the agricultural character of the province and the prevalence of secondary and service industries.

During an inventory of hazardous wastes in 1981 a Joint City-Provincial Task Force [16] recorded 8783 tonnes per year generated in the City of Winnipeg; not much different from the 7881 tonnes given for the Winnipeg region in this report.

Based on the above, it can be concluded that the information on generated quantities in this report is accurate within about a 10 percent margin, for the time period under examination. In addition, while the present 20,253 tonnes per year figure may not be exact, the percentage breakdown of the quantities per industry, class, region and treatment/disposal can be considered sufficiently accurate for the purpose of choosing among the management system options. At the conceptual level the kind of waste and its location is more important than the exact quantity.

3. Present Landfill Sites

Landfilling of hazardous waste accounts for approximately one fifth of the waste identified by the Information Exchange. It is essential to review current land disposal practices in order to assess their impact on the environment and the public health.

Redirecting nonlandfillable wastes to other treatments and directing landfillable hazardous wastes to facilities which are more environmentally suited to handle their disposal may be a good interim solution. Over the long term, various technologies may become available for the treatment of hazardous waste and therefore various designs of overall treatment facilities are possible. With all conventional treatments (see section 6) there is also a need for an environmentally safe, properly designed landfill.

Although many substances may be landfilled if proper pretreatment is undertaken, a number of substances should not be included in landfill operations because of their chemical make-up and potential hazard. Nonlandfillable wastes include explosive or radioactive wastes, compressed or flammable gases, and poisonous or infectious substances. Any substance which produces a combustible product when wet should not be landfilled. Liquid disposal in a landfill is undesirable, since fluids percolating through the landfill may leach into groundwater [8]. Containerized liquids can also be a problem because most containers will deteriorate over time. Liquids escaping from the containers create spaces within the landfill structure and cause unstable settling of the waste. Those liquids which may also destroy landfill liners would have to be excluded (e.g. solvents).

A study concentrating on site-specific investigations of the environmental impact of landfills, carried out under the auspices of the federal and provincial Governments, has been ongoing since 1981. In addition, during 1984 a survey of 75 active landfill sites in Manitoba was carried out in the vicinity of major industrial centers, selected areas where large amounts of agricultural chemicals were likely to be used, and areas where hazardous waste generators were located. The purpose of this survey was to assess the physical characteristics and current waste management practices at these landfill sites.

Federal-Provincial Landfill Study

Although records have been kept on most active landfill sites and information on major disposal sites was relatively extensive, prior to 1981 there was no comprehensive overview of both active and inactive waste disposal grounds. In late 1981 the federal and provincial

Governments undertook a joint study with the following objectives:

1. Identification and verification of the locations of active and inactive disposal sites, together with available data on the nature and quantity of the materials deposited therein;
2. Preliminary assessment of the manifest or potential impact of each site on the environment;
3. Examination of the candidate sites to verify the preliminary assessment, with recommendations made regarding the mitigation of potential problems and the undertaking of remedial measures if necessary.

The initial inventory of landfill sites rated them in regard to the data available on potential contact with the water table, proximity of wells, waterbodies and communities as well as such factors as the general type of waste and the level of environmental and health concern for various wastes disposed of at each site [14].

A second series of reports provides considerably more detailed information and tends to confirm data from the initial inventory regarding whether or not there is significant migration of contaminants and the potential impact from these contaminants. Some recommendations for the mitigation of these problems have been made [21; 35-39]. The Federal Provincial Landfill Study is ongoing with regard to site-specific investigations and further reports are being prepared for release in 1985.

Provincial Survey, 1984

Methods

The survey was carried out to assess current waste management practices at landfill sites. The Information Exchange data (Section 2) on file with the provincial Department of Environment and Workplace Safety and Health, and literature produced through the Federal/Provincial Study were used as source material. The Information Exchange data were utilized to indicate industrial concentrations and where hazardous waste is presently landfilled.

Due to the costs involved in transporting wastes over long distances landfill site surveys were restricted to 25 kilometers or less from the center of any selected community (Figure 6). In some cases communities were small enough that it was unlikely that industrial wastes would be transported further than the local landfill site. Therefore only one site was examined at each of these locations. Not all hazardous waste comes directly from industrial sources and therefore some effort was made to examine active landfill sites in the vicinity of predominantly agricultural communities in southwestern Manitoba.

From the 184 waste disposal grounds identified for study during the initial literature and file review, 109 were eliminated: those which were closed, recommended for closure, very small, or used privately or exclusively by federal or provincial establishments or Crown corporations. The other 75 sites were inspected during the 1984 field season and observations were made regarding the parameters listed in Table 12.

Rating

Table 12 was utilized to grade landfill sites with respect to the potential for hazardous waste impact on these sites.

Each parameter was arbitrarily assigned a score from 1 to 5, with the lowest numbers indicating the highest risk, the higher numbers indicating safer conditions from a public health or environmental point of view. From the assigned scores for each parameter a rating for each site was derived. The ratings for the 75 active landfill sites are presented in Table 13.

The ten sites which appear from this initial rating to have the best potential for interim hazardous waste disposal are:

Northern Region, 3: Thompson, The Pas, Flin Flon;
Parklands Region, 2: Dauphin, Durban;
Southern Region, 2: Winkler, Morden
Western Region, 2: Brandon, Killarney;
Winnipeg Region, 1: Brady Road Landfill Site.

At the present time the Selkirk site scheduled to open in 1985 holds the most promise for the Eastern Region.

The above are the highest-scoring sites in each region. However, all of the ratings, including the totals, are only to be used for general comparison of the relative merits of individual sites, not as a definitive assessment of their suitability for specific hazardous wastes. Before any site can be licensed or granted a temporary operating permit for interim hazardous waste disposal, intensive field investigations, monitoring programs, and an assessment of the specific waste must be carried out, and an environmental impact assessment should be conducted.

Discussion

The survey revealed that hazardous wastes of all varieties are being disposed of in Manitoba's municipal landfill sites. Containers of various chemicals and compounds were noted at nearly all the sites: oil, solvent, gasoline, tar, adhesives, paints, photographic chemicals, seed-treatment chemicals, and hospital wastes were among the most common ones. An attempt to segregate pesticide containers from the rest of the waste is being undertaken at waste disposal grounds in most agricultural areas of the province. These containers are rinsed, crushed and the residues collected for disposal at a proper treatment facility [29].

Figure 6. Landfill sites surveyed during 1984

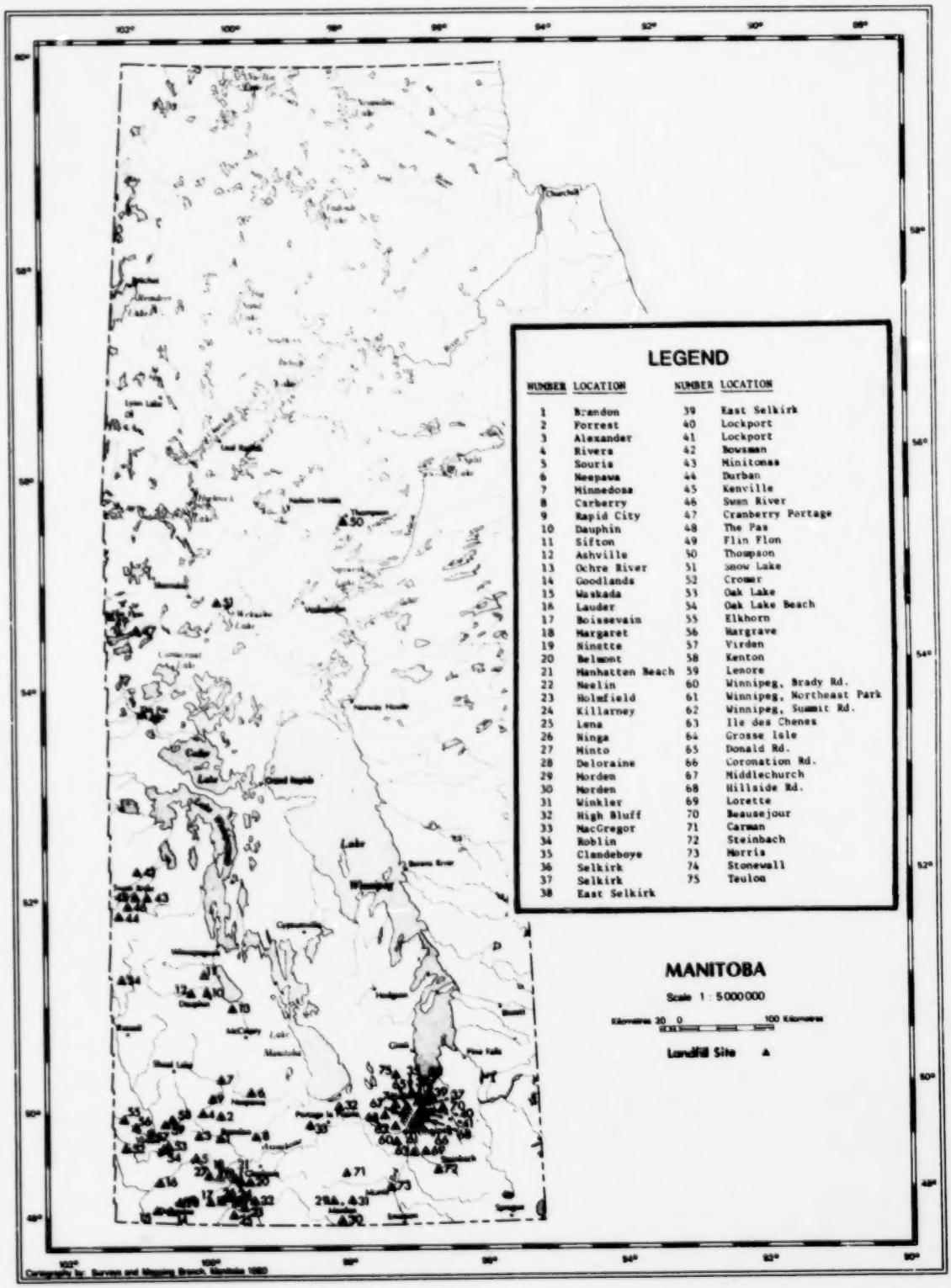


Table 12: Rating system used in the assessment of the 75 active landfill sites

PARAMETERS		VALUES AND RATING SCORE				
		1	2	3	4	5
GROUNDWATER	POTENTIAL CONTAMINATION	high	moderate	low	unlikely	highly unlikely
RUNOFF	SLOPE (OF LOCAL TERRAIN) AND CONTAINMENT	steep with sloping waste pile	steep with level waste pile	moderate	slight with waste piled	level with pit or trench
	WATER BODY CONTACT	occurring	probable	possible	direct, unlikely	unlikely
GEOLOGY	SURFACE OR SUBSURFACE	sand and gravel or undetermined	fractured shale, limestone and sandstone or precambrian rock and bog	clay, silt sand and gravel till or equivalent	clay boulder till or equivalent	clay
SIZE	(hectares)	0-5	6-10	11-20	21-40	over 40
SUPERVISION AND MAINTENANCE		low, occasional	moderate, occasional	good, occasional	moderate, daily	good, daily
FENCING AND CONTROL		none	partly	complete & no gate or partial & gate	complete with gate	complete with weigh scale
SEPARATION OF WASTE		none	partly	moderate (specific waste areas)	good (several waste areas)	best, (good & well organized)
PROXIMITY TO MAJOR/MINOR CENTRES		distant from both	moderately close to minor	moderately close to major	close to minor	close to major

Table 13: Ratings of 75 active landfill sites

SITE NO.	REGION MUNICIPALITY	TOWN OR COMMUNITY	LOCATION	GROUNDWATER	SLOPE AND CONTAINMENT	WATER BODY CONTACT	SURFACE GEOLOGY	SUBSURFACE GEOLOGY	SIZE	SUPERVISION AND MAINTENANCE	FENCING AND CONTROL	WASTE SEPARATION	PROXIMITY TO CENTRES	TOTAL
	EASTERN REGION													
70	Brokenhead, R.M.	Beausejour	SW 16-13-7E	2	4	5	1	3	4	2	1	1	3	26
74	Rockwood, R.M.	Stonewall	NE 19-13-2E	4	4	5	5	2	2	3	4	3	3	35
75		Teulon	SW 30-16-26E	2	5	5	3	2	3	2	1	3	3	29
35	St. Andrews, R.M.	Clandeboye	SW 34-14-4E	5	4	5	3	3	1	3	2	3	3	32
65		St. Andrews (Donald Rd.)	SW 13-13-3E	5	4	5	3	3	4	2	2	2	3	33
36		Selkirk	SE 18-14-5E	5	Site to open in 1984/85				2		4		5	?[b]
37		Selkirk	R.L. 56 Parish of St. Clements	2	4	5	1	2	2	3	2	1	5	27
38	St. Clements, R.M.	East Selkirk	R.L.'s 236 and 241 Parish of St. Peters	2	5	5	1	3	1	2	1	1	3	24
39		East Selkirk	SE 13-14-5E	4	5	5	4	4	1	3	2	3	3	34
40		Lockport	RL. 133 Parish of St. Clements	2	5	5	1	3	2	2	2	3	3	28
41		Lockport	R.L.'s 265 and 266 Parish of St. Andrews	4	5	5	5	3	1	3	3	2	3	34
	NORTHERN REGION													
47	Consol, LGD	Cranberry Portage	NE 7-65-26W	4	4	4	2	2	3	2	2	3	3	29
48		The Pas	SE 14-56-26W	2	4	3	2	3	4	3	3	3	5	32
49	Flin Flon, City	Flin Flon	SW 32 & NW 29-66-29W	2	2	3	2	3	3	4	3	2	5	29
50	Mystery Lake, LGD	Thompson	Twp. 77-Rges. 3 and 4W at PR 391	2	1	3	2	2	5	4	4	3	5	31
51	Snow Lake, Town	Snow Lake	1.1 km south of Snow Lake off PR 392	2	3	3	2	2	1	2	1	2	5	23
	PARKLANDS REGION													
10	Dauphin, R.M.	Dauphin	SW 20-25-19W	5	4	4	5	4	5	4	3	4	5	43
11		Sifton	NW 35-27-20W	2	5	4	3	3	2	2	1	1	2	25
12	Gilbert Plains, R.M.	Ashville	NE 22-25-21W	2	5	4	3	3	1	2	2	1	2	25
42	Minitonas, R.M.	Bowsman	SW 24-38-27W	2	5	4	3	3	1	2	4	1	2	27
43		Minitonas	SW 17-30-25W	2	5	4	1	3	1	2	4	1	2	25
13	Ochre River, R.M.	Ochre River	SW 12-24-17W	2	5	5	3	3	2	1	1	1	2	25

Table 13: continued

SITE NO.	REGION MUNICIPALITY	TOWN OR COMMUNITY	LOCATION	GROUNDWATER	SLOPE AND CONTAINMENT	WATER BODY CONTACT	SURFACE GEOLOGY	SUBSURFACE GEOLOGY	SIZE	SUPERVISION AND MAINTENANCE	FENCING AND CONTROL	WASTE SEPARATION	PROXIMITY TO CENTRES	TOTAL
34	Shell River, R.M.	Roblin	SE 20-26-28W	2	3	4	1	3	1	2	3	3	4	26
44	Swan River, R.M.	Durban	SW 24-34-29W	2	5	5	5	4	1	3	3	3	3	34
45		Kenville	NE 24-35-28W	2	5	5	1	4	1	3	2	3	3	28
46		Swan River	NE 15-36-27W	2	5	3	3	2	2	4	3	5	5	34
	SOUTHERN REGION													
71	Dufferin, R.M.	Carman	NW 13-6-5W	3	4	5	3	1	3	1	3	2	4	29
72	Hanover, R.M.	Steinbach	NW 23-6-6E	2	1	5	3	1	4	3	2	1	4	26
73	Morris, R.M.	Morris	NE 3-5-1E	3	4	4	3	1	2	1	1	2	4	25
32	Portage la Prairie, R.M.	High Bluff	S 22-13-5W	4	5	5	1	4	2	2	2	3	3	31
63	Ritchot, R.M.	Ile des Chenes	SW 32-8-4E	4	4	5	3	3	3	3	3	2	3	33
29	Stanley, R.M.	Morden	E 10-3-6W	2	4	4	3	1	3	4	4	4	5	34
30		Morden (south of)	NW 16-1-5W	3	1	2	3	1	3	1	2	3	3	22
31		Winkler	SW 23-3-4W	4	4	4	4	4	1	3	3	1	5	33
69	Tache, R.M.	Lorette	NE 31-8-5E	3	4	4	3	1	1	2	3	3	3	27
	WESTERN REGION													
1	Brandon, City	Brandon	NW 17-10-18W	2	5	4	4	1	4	5	5	2	5	37
14	Brenda, R.M.	Goodlands	SW 11-2-24W	2	5	3	3	1	1	2	2	2	1	22
15		Waskada	SE 5-2-25W	2	4	5	3	3	1	2	2	1	1	24
16	Cameron, R.M.	Lauder	SW 17-6-23W	2	4	5	3	1	1	2	3	3	1	25
4	Daly, R.M.	Rivers (1983)[a]	SW 25-12-21W	1	4	3	1	1	1	2	2	2	3	20
2	Elton, R.M.	Forrest	NW 8-12-18W	2	3	3	2	3	1	2	2	2	5	25
5	Glenwood, R.M.	Souris	NE 34-7-21W	2	2	3	1	3	1	2	4	2	4	24
6	Langford, R.M.	Neepawa	SE 34-14-15W	2	3	4	3	1	2	1	4	3	3	26
7	Minto, R.M.	Minnedosa	NE 4-15-18W	2	2	4	2	3	2	2	1	2	3	23
17	Morton, R.M.	Boissevain	NE 13-3-20W	2	4	3	3	1	1	2	1	3	4	24
8	North Cypress, R.M.	Carberry	SE 35-10-15W	2	3	4	1	3	3	2	2	1	3	24
33	North Norfolk, R.M.	MacGregor	SW 11-12-10W	2	5	4	1	1	3	2	1	2	3	24
52	Pipestone, R.M.	Cromer	NE 4-9-28W	2	4	4	1	3	1	2	3	1	2	23
18	Riverside, R.M.	Margaret	NW 33-5-18W	2	4	3	3	3	1	2	2	1	1	22
19		Ninette	SW 24-5-17W	2	2	4	3	2	1	2	2	2	2	22
9	Saskatchewan, R.M.	Rapid City (1983)[a]	SE 30-13-19W	4	4	4	1	5	2	2	1	1	3	27
53	Sifton, R.M.	Oak Lake	SE 23-9-24W	2	3	4	1	3	1	2	2	2	3	23
54		Oak Lake Beach	SE 31-8-24W	1	3	3	1	1	1	2	1	1	1	15
20	Strathcona, R.M.	Belmont	NW 17-5-15W	2	3	4	3	1	1	2	3	3	1	23

Table 13: continued

SITE NO.	REGION MUNICIPALITY	TOWN OR COMMUNITY	LOCATION	GROUNDWATER	SLOPE AND CONTAINMENT	WATER BODY CONTACT	SURFACE GEOLOGY	SUBSURFACE GEOLOGY	SIZE	SUPERVISION AND MAINTENANCE	FENCING AND CONTROL	WASTE SEPARATION	PROXIMITY TO CENTRES	TOTAL
21		Manhattan Beach	NE 8-5-16W	4	1	4	2	2	1	2	3	3	2	24
22		Neelin	E 24-3-15W	2	4	4	4	4	1	2	3	3	2	24
23	Turtle Mountain, R.M.	Holmfield	SE 25-2-16W	2	5	4	1	3	1	2	2	2	2	24
24		Killarney	NE 7-3-16W	2	3	4	5	3	5	3	3	4	4	35
25		Lena	NW 26-1-17W	4	4	4	3	3	1	2	3	3	2	29
26		Ninge	NW 19-3-18W	2	5	2	2	3	1	2	2	3	2	24
55	Wallace, R.M.	Elkhorn	NW 3-12-28W	2	5	4	1	3	1	2	2	1	3	24
56		Hargrave	SW 2-11-27W	2	5	4	4	3	1	2	3	3	3	30
57		Virden	NE 14-10-26W	2	3	2	1	3	2	2	2	2	5	24
3	Whitehead, R.M.	Alexander	SW 16-10-21W	2	2	4	5	1	1	2	3	2	3	25
27	Whitewater, R.M.	Minto	SE 7-6-19W	4	5	4	3	3	1	2	2	3	2	29
28	Winchester, R.M.	Deloraine	SE 11-3-23W	2	4	4	3	1	1	2	3	3	4	27
58	Woodworth, R.M.	Kenton	NW 1-12-24W	2	4	4	1	1	1	2	3	3	2	23
59		Lenore	31-11-24W	2	4	4	3	1	1	2	2	1	2	22
	WINNIPEG REGION													
66	East St. Paul, R.M.	Birds Hill	near Coronation Road OTM 62-20A	4	5	4	5	3	2	1	3	1	3	31
64	Rosser, R.M.	Grosse Isle	L.S. of 3 30-12-1E	4	4	4	3	1	1	2	2	2	3	26
68	Springfield, R.M.	Cooks Creek (Hillside Road)	NE 5-12-5E	2	2	4	3	1	4	3	3	2	3	27
67	West St. Paul, R.M.	Middlechurch	NE 30-12-3E	4	5	4	3	3	2	3	3	1	3	31
60	Winnipeg, City	Winnipeg, Brady Road	R.L.s 88 through 91 Parish of St. Norbert	5	5	4	5	5	5	5	5	2	5	46
61		Winnipeg, Northeast Park	Springfield Rd. east of Lagimodiere Blvd.	5	5	4	5	3	5	5	5	2	5	44
62		Winnipeg, Summit Road	St. James Assiniboia, between Summit Rd. and Perimeter Hwy.	2	5	4	5	2	5	5	5	2	5	40
	Mean Values			2.6	3.9	4.0	2.7	2.4	2.0	2.4	2.5	2.2	3.2	27.8

a: Sites at Rapid City and Rivers were surveyed in 1983 and not in 1984.

b: Site at Selkirk was not open for operation at the time of the survey and could not be rated properly

Over the next few years, until a comprehensive waste management program is developed for Manitoba, existing land disposal sites will undoubtedly be used for disposal of many hazardous wastes. During this time, through evaluation and assessment we should endeavour to redirect non landfillable wastes for treatment at facilities more suited to handling their particular hazards and direct landfillable wastes and pretreated residues to those active waste disposal grounds which offer the best protection to the public health and the environment.

4. Existing Sewage Facilities

Sewering of waste materials and products accounts for half of the waste reported in the Information Exchange, second only to air emissions. Although relatively convenient, it is not the ultimate solution for disposal of certain wastes, especially those which do not undergo the rapid breakdown required in sewage treatment.

Waste products that do not break down should be detectable in their primary forms in the sewage treatment facilities. This section deals with the effluent quality at selected sewage treatment plants and lagoons.

Methods

Investigation followed a pattern similar to the landfill study. Selected were sewage facilities for areas of denser population with industries that were identified through the Information Exchange as being hazardous waste producers.

Sewage facilities within 25 km from each center were sampled. In the northern region were surveyed those at Thompson, Flin Flon and The Pas. With the exception of Thompson and Winnipeg, there was only one sewage treatment facility per community.

In total, 28 sites were sampled during August and September, 1984, to assess the current contaminant levels. Lagoons were sampled by collecting a grab sample (from shore) from a secondary cell, or in the case of multiple cells, from the cell from which the effluent was released. Treatment plants were sampled as close to the point of effluent release as possible, in some cases at the effluent outfall. All samples were analysed in duplicate, at the W.M. Ward Technical Services Laboratory. The 36 parameters analyzed, pesticides, metals, and other chemical compounds are listed in Table 14.

Results and Discussion

Uniform regulations are currently being proposed by federal and provincial governments. In the interim the same approach was adopted as in Ontario, and the guidelines of the Ontario Ministry of Environment [25] were followed in determining whether any wastes were present in the effluent in hazardous concentrations. "Hazard limit" in this context (Table 14) means a concentration equal or greater than 10 times the drinking water quality guideline for the respective substance [12].

The present survey of sewage facilities indicated that none of them were significantly contaminated by any of the parameters analyzed. A table of all analytical results of the survey is unwieldy, therefore the only results

which were tabulated were those which gave a reading above the respective analytical detection limit. All concentrations listed in Table 15 are lower than the hazard limits shown in Table 14. The analysis, however, indicated the presence of many organics which were not able to be separated and identified with the currently available equipment. The aim is to eventually fulfill all analytical requirements by the addition of new instruments and/or by contracting out certain analyses to recognized certified laboratories.

Table 14: Parameters analyzed in the sewage samples, detection limits, and hazard limits.

Parameters	Detection Limit µg/L	Hazard Limit µg/L
PESTICIDES		
aldrin	0.02	7
c-chlordane	0.04	70
t-chlordane	0.03	70
2,4-D	0.5	1000
2,4-DB	0.94	NS
op-DDD	0.07	300
pp-DDD	0.09	300
op-DDE	0.04	300
pp-DDE	0.03	300
op-DDT	0.07	300
pp-DDT	0.08	300
diazinon	0.2	140
dieldrin	0.04	7
endrin	0.08	2
ethylparathion	0.5	70
lindane	0.01	40
malathion	0.5	NS
methoxychlor	0.30	1000
methylparathion	1.0	70
silvex	0.24	100
2,3,5-T	0.24	NS
treflan	0.06	NS
METALS		
arsenic	1.	500
cadmium	1.	500
chromium	5.	500
copper	10.	10000
lead	5.	500
mercury	.05	10
nickel	5.	NS
selenium	1.	100
silver	10.	500
zinc	10.	50000
CYANIDES (total)	0.02	2000
POLYCHLORINATED BIPHENYLS (total)	0.50	30
NITROGEN NO_3, NO_2	0.01	100000
pH	NS	NS

NS = not specified

5. Analytical Requirements and Capabilities

Analysis is required within the framework of a waste management system for initial evaluation of waste streams, development of appropriate treatments, and subsequent monitoring and enforcement. As well monitoring of waste streams for the breakdown products of wastes is important because in some cases they may be more dangerous than the waste itself.

In 1980 the United States Environmental Protection Agency (EPA) published a "priority list" of water pollutants. It contains chemicals which are not only hazardous in themselves, but are also indicative of possible presence of further hazardous materials [3]. Although the list applies primarily to water pollutants, it also can be used to assess wastes in general.

Present capabilities of the provincial laboratories are limited in respect to this EPA priority pollutant list. However, given necessary upgrading of equipment the major requirements will be fulfilled. All analytical capabilities presently available were established because of the presence of known contaminants of the environment and therefore cover most problem areas. Regulations, however, generally tend to be more and more stringent, and may soon require analysis of other contaminants.

Of the 142 substances identified by the Information Exchange 45 (39%) either are on the EPA list or contain components which are on the list. At present, 31% of the wastes cannot be analyzed at all, and 20% can be partially analyzed. A summary of the current analytical capabilities, by hazardous waste class, is presented in Table 16.

Comparison of the capabilities of analysis of the various classes to the volume of wastes produced for each class shows major shortcomings in flammable liquids and flammable solids (Classes 3 and 4) and less serious deficiencies in the remaining classes. Upgrading the organic analysis area would overcome the most serious deficiencies. Omission of necessary upgrading of capability would require contracting out analysis in serious cases to recognized certified laboratories, at a high cost.

Table 15: Results of analyses of sewage samples [1, 2]

Lagoons Tested		Lindane µg/L	Treflan µg/L	2,4-D µg/L	Hg-T µg/L	Pb-T µg/L	As-T µg/L	Cr-T µg/L	CN-T µg/L	pH
Boissevain				1.9			6			8.32
Brandon							5			7.67
Dauphin							12		60	8.11
Deloraine							10			8.50
Flin Flon			21		.78	8	6			7.27
Ile de Chenes							31			8.84
Killarney		.15			.06		3			7.47
La Salle							29			8.87
Lorette							7			8.30
Medora							66			8.04
Miami					.07		1	70		7.52
Minto				.91			24			9.00
Morden						8	3	16		7.67
Oakville							11			8.65
Plum Coulee							21			9.62
Portage					.19	6	6	6		7.15
St. Adolphe							8			9.17
Selkirk		NA[3]		1			1			7.60
Steinbach							4			7.99
Swan River							10			7.77
The Pas		.05	.13				1			7.27
Thompson	2	.04					1		25	7.50
Thompson	1	.13			.22	11	1		25	7.49
Virden					.09	15	33		100	7.57
Winkler							13	9	65	7.90
Winnipeg	N	.05		2.2	.12		3		100	6.65
Winnipeg	S	.04					2			6.62
Winnipeg	W	NA	NA				2			7.37

[1] = Concentration below the detection limits as listed in Table 14 are not included.
[2] = Zinc, copper and nickel were found in all samples, below hazard limits.
[3] = Not analyzed for.

Table 16: Current capability of analyzing for substances in different hazardous waste classes

Class	Volume Generated (tonnes/year)	% Analyzed[1] (% No. of Substances)
2 Compressed Gases	335	50
3 Flammable Liquids	3180	9
4 Flammable Solids	580	29
5 Oxidizing Agents	223	50
6 Acute Toxic	593	50
8 Corrosives	4942	68
Miscellaneous		
9 Environmental Toxic	382	60
Aquatic Toxic		62
Chronic Toxic[2]	NA	NA[3]

1. These percentages represent those substances which can be totally analyzed. Many more can be partially characterized.
2. The number and type of waste streams in the chronic toxic class for Manitoba has not been totally defined at the present time. Analytical capabilities exist mainly in the metals analysis area. Note 1. also applied.
3. Not applicable.

6. Available Technology

Several different groups of methods are used for the treatment and disposal of hazardous wastes. They include waste utilization, chemical and physical treatments, incineration, and landfill disposal. The objective of all methods is to reduce either the volume, the toxicity or the particular hazard of the initial material. None of these methods, however, is a complete panacea because some hazardous residue always results.

Waste Utilization

One characteristic of our industrialized society is its "disposable" life style where so many commodities have a limited (e.g. one time) life span. The inevitable consequence of such life style is waste which depletes our resources and generates discarded material with its troublesome disposal. The problem can be alleviated when it is realized that "waste is material for which no further value is recognized by the individual or a company producing it" [26]. Can waste be treated for reuse for the original purpose? Can it be used as raw material for another process? In the first instance it is recycled, in the second there is either materials or energy recovery.

Waste utilization is an invaluable component of hazardous waste management. Whereas most municipal wastes do not pose an ultimate threat, hazardous wastes do. The benefits of utilization of hazardous waste are obvious. Fortunately considerable waste utilization occurs presently in Manitoba. The inventory indicated that 1955 tonnes/year of hazardous waste is being recycled, nearly 9% of the total (Table 11). The potential for greater utilization of hazardous wastes certainly exists. It can be attained by a combination of recycling and resource recovery. Many materials currently are being discarded because of contamination during an industrial process and/or because it is easier to secure the raw material. One example is the acetone used in the manufacture of fiberglas products. Purification of the used acetone would enable it to be used again and again and thereby eliminate its disposal. An example of energy recovery is the use of flax shives, currently an agricultural waste, as fuel in cement kilns. It is estimated that its use at one particular plant "will reduce the natural gas consumption in the kiln by at least 30% . . . a net fuel savings in excess of $1 million per year" [5].

Since waste denotes ignorance of further use of a product, a concept, called Waste Exchange, has evolved to overcome this deficiency. It simply provides a notification service of the availability of specific wastes. Interested persons can then contact prospective suppliers and a transaction may result. A service called the Manitoba Waste Exchange became operational on December 11, 1984 and may be contacted by phoning 257-3891. It is a "Branch Office" of the Canadian Waste Materials Exchange of Mississauga, Ontario. That service, started in 1976, has been reasonably successful in providing waste reuse opportunities [20]. From Jan. 1978 to Sept., 1984, it listed 2,146 wastes. Transfers occurred in 437 (20%) of the listings. An estimate of their "replacement" value is $6.5 million/year. Judging from these activities, it is probable that the Manitoba Waste Exchange will increase the utilization of Manitoba's industrial wastes.

Physical Treatment

Physical treatment of hazardous wastes acts on their physical character by separating the components or changing the physical form. The usual objective is to reduce the volume by generating an effluent and a residual sludge or concentrated waste. The treated effluent may then be either reintroduced into the industrial process or discharged to sewers, etc. No single physical treatment is applicable to all wastes and usually the appropriate method is specific to the type of hazardous waste. Many kinds of physical treatment have been suggested, one author listing 30 processes (Table 17) [6].

Table 17: Physical treatment process for hazardous wastes

Air Stripping	High Gradient Magnetic Separation
Calcination	Ion Exchange
Carbon Adsorption	Liquid Ion Exchange
Centrifugation	Liquid-Liquid Extraction of Organics
* Dialysis	* Microwave Discharge
Dissolution	Neutralization and pH Content
Distillation	Precipitation
* Electrodialysis	Resin Adsorption
Electrophoresis	Reverse Osmosis
Evaporation	Sedimentation
Filtration	Steam Distillation
Flocculation	Steam Stripping
Flotation	Suspension Freezing
Freeze Crystallization	Ultra Filtration
* Freeze Drying	* Zone Refining

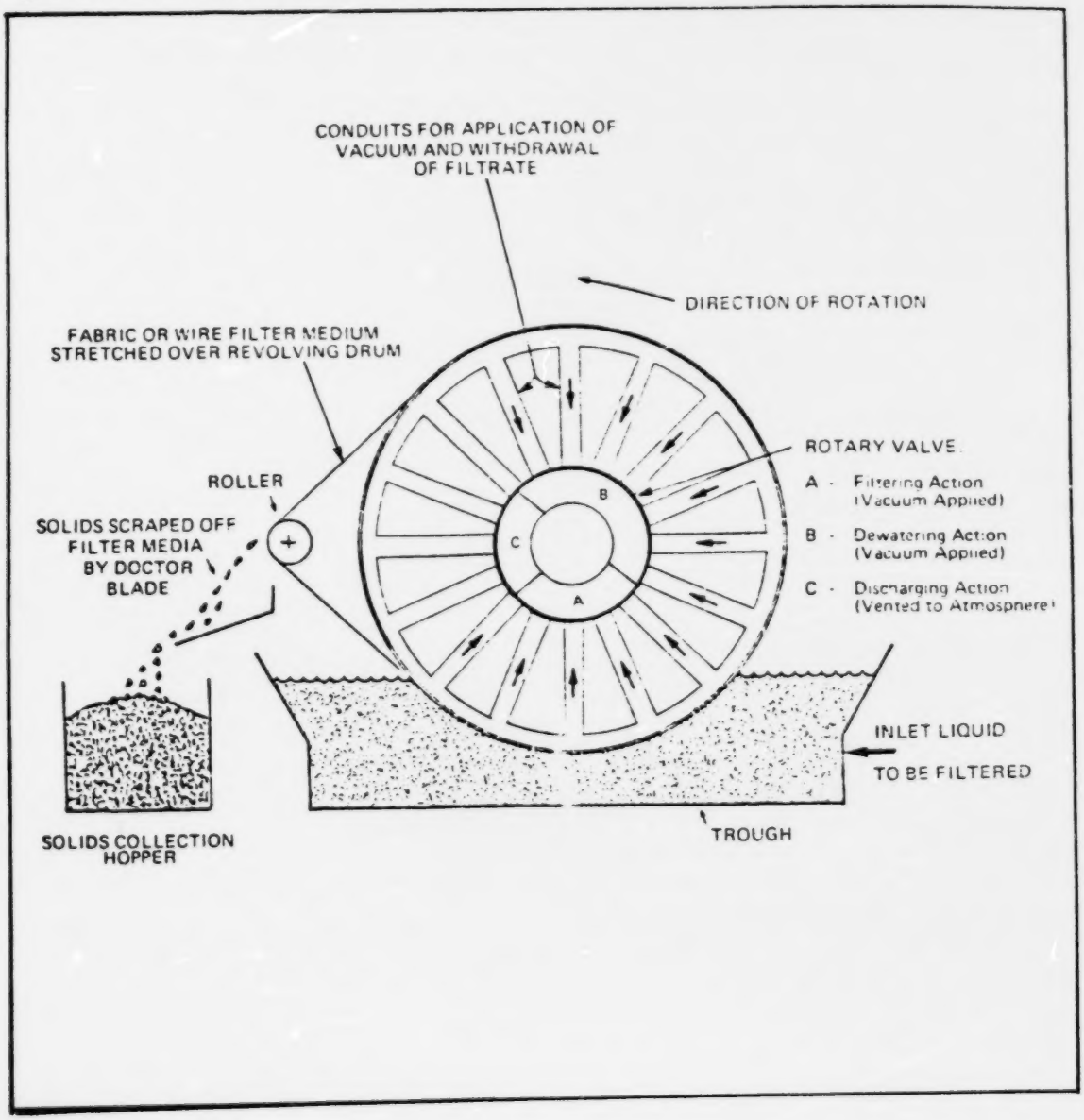
From Capellini 1979. [6]

*Not considered technically or economically feasible by author

Filtration
This is one obvious method whereby the particles suspended in a fluid are separated by forcing it through a porous medium. Various materials can serve as the filter — sand, coke, porous ceramic, diatomaceous earth, or filter cloths (Figure 7). The pressure differential to move the fluid can be induced by gravity, positive pressure, or vacuum. As a dewatering process, filtration only concentrates the wastes, hence reducing transportation and disposal costs. It is not designed to environmentally improve the filtrate beyond making it more amenable to further treatment.

Evaporation
In this physical treatment the liquid waste portions are vapourized so as to separate them from the dissolved or suspended material. It is similar to distillation except that no attempt is made to collect the vapours. Because the solvent being evaporated is usually water, there are generally no pollution problems with evaporation vapours. When they contain hazardous material, some other pollution control device is required to remove the offensive material. Evaporation ponds may sometimes be used. Their siting must receive serious scrutiny to avoid any adverse

Figure 7. Rotary drum vacuum filter (cross-sectional view). From Reid, Crowther et al. 1980


CONDUITS FOR APPLICATION OF VACUUM AND WITHDRAWAL OF FILTRATE
DIRECTION OF ROTATION
FABRIC OR WIRE FILTER MEDIUM STRETCHED OVER REVOLVING DRUM
ROTARY VALVE
A - Filtering Action (Vacuum Applied)
B - Dewatering Action (Vacuum Applied)
C - Discharging Action (Vented to Atmosphere)
ROLLER
SOLIDS SCRAPED OFF FILTER MEDIA BY DOCTOR BLADE
INLET LIQUID TO BE FILTERED
TROUGH
SOLIDS COLLECTION HOPPER

environmental effects upon the adjoining area, the underlying soil, or groundwater. Evaporation is used for example to solidify the alkaline waste from carbide manufacture.

Chemical Treatment

Many hazardous wastes can be treated chemically to alter their composition and therefore reduce their potency. The objective is to alter the chemical structure of the material. Like physical methods, no general chemical method is applicable to all hazardous wastes. Individual methods, listed in Table 18, can only be applied to specific situations.

Table 18 Chemical treatment processes for hazardous wastes

Chemical Oxidation	Neutralization
Chemical Reduction	Ozonation
Hydrolysis	Photolysis
Liquid-liquid solvent extraction	

From Metry 1979. [24]

Oxidation

This basically alters the electron status of the waste. Liquids are the primary waste form treatable by chemical oxidation which has only limited application to slurries, tars and sludges. Oxidation is among the most common of chemical reactions. Two examples are the conversion of cyanides in metal plating plants to cyanates by hydrogen peroxide and the detoxification of certain pesticides (e.g. Paraquat) by the use of potassium permanganate [4].

Neutralization

Here the effluent is rendered less acidic or less basic by adding a suitable chemical which changes its pH making it less harmful. This method usually results in the formation of insoluble salts containing the waste components. Neutralization is used to treat liquid, gaseous, or solid wastes. It is accomplished by the addition of an alkaline to an acidic material or an acidic to an alkaline one, the amounts determined by the required final pH. The reaction's end products are a salt and water, e.g:

Hyrochloric Acid + Sodium Hydroxide = Water + Sodium Chloride

The product, salt in aqueous solution, is neutral with a pH of 7. Neutralization may be carried out in tanks, ponds, adsorber columns or in various other equipment. The most important auxiliary equipment is that required for pH measurements.

Incineration

Burning is one of the oldest disposal methods. In the Middle Ages, a flaming wagon was hauled through London so that residents could get rid of their garbage. Modern incineration methods are now more sophisticated but have the same objective of reducing the bulk of the feed substance and rendering it harmless. Combustion of certain hazardous wastes is possible by various types of equipment (Table 19). However auxiliary equipment is needed for an incineration facility (Figure 8). Although not shown, the facility's first equipment would be a weigh scale to confirm that the load corresponds to the manifest. The second additional equipment would be storage containers for the incoming material allowing for operations outside of delivery hours[1]. Another area would be for "feed preparation and blending" to attain the most desirable mix for the incinerator's operating characteristics. Incinerated materials are not completely consumed. There is always residue which must be disposed of in an environmentally acceptable manner which predisposes a secure landfill. The usually toxic fumes associated with combustion must be rendered innocuous by various pollution control devices such as precipitators and scrubbers. Thus while an incinerator per se can dispose of hazardous wastes, much peripheral equipment is required.

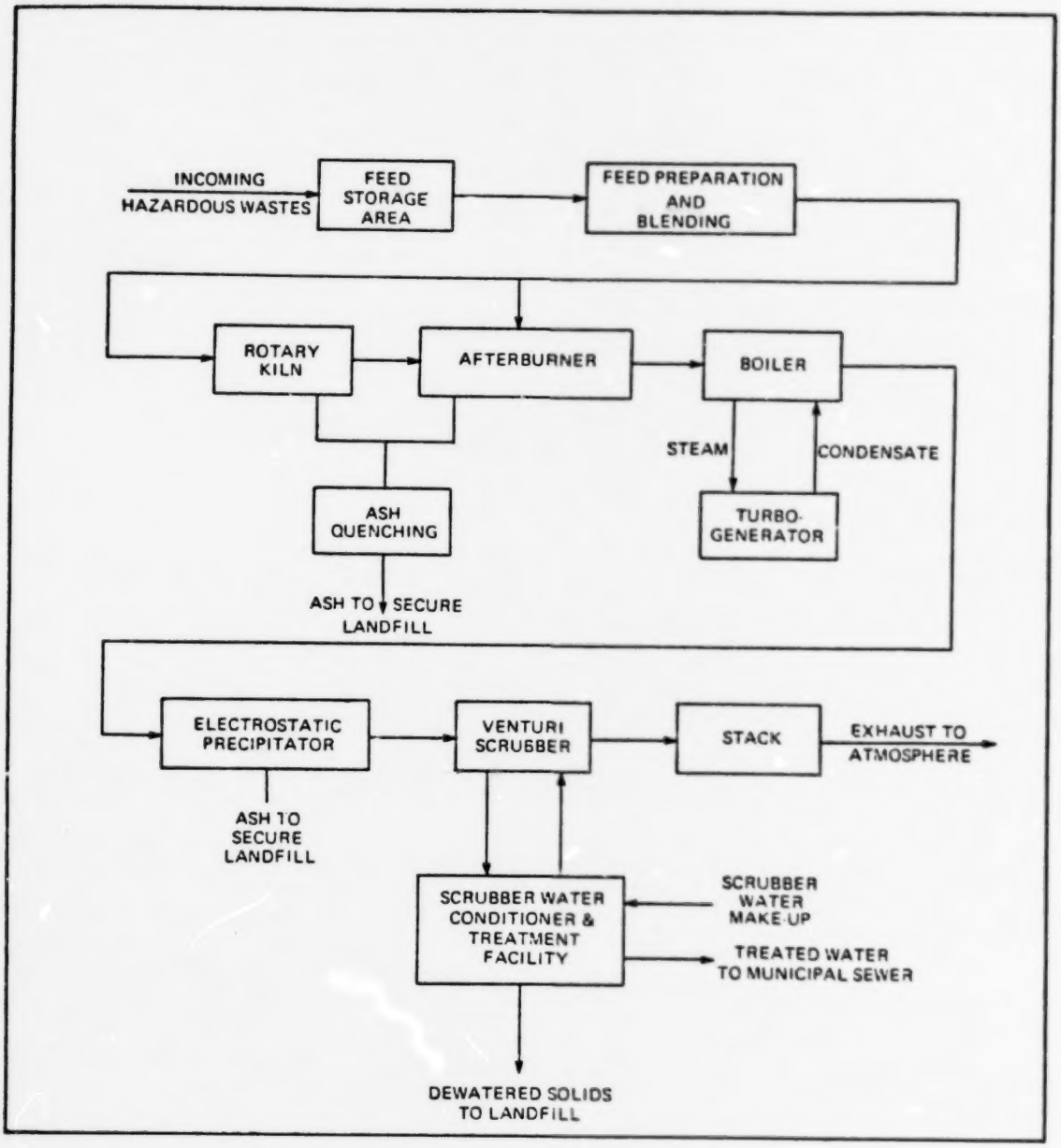
Table 19: Types of incinerators for hazardous wastes.

Fluidized bed	Multiple chamber
Gas combustion	Multiple hearth
Liquid injection	Pyrolysis
Plasma destruction	Rotary kiln
Molten-salt	Wet oxidation

After Scurlock 1975 [31]

[1]These two kinds of equipment are not specific to incinerators only; they would be needed with any treatment facilities.

Figure 8. Rotary kiln flow schematic; GSB plant at Ebenhausen, West Germany.



Incinerator Types

There are many different kinds of incinerators (see Table 19). The salient features of the best known ones are briefly discussed below.

Fluidized Bed Incinerator

The fluidized bed incinerator is a vertical structure, typically 33 feet high, which utilizes a bed of sand to combust the injected waste (Figure 9). Air forced into the bottom of the bed agitates the sand. Combustion occurs within the bed itself or in the freeboard area. This incinerator operates most effectively with liquid or gaseous substances but can also dispose of solids. It is not well suited to bulky wastes, tarry solids or wastes with a fusible ash content. Another disadvantage is the difficulty of removal of the inert residual material from the bed. Its first commercial use in the United States was in 1962. It is presently unsuitable as a hazardous waste facility because of its unproven design and operating parameters [23].

Liquid Injection Incinerator
As indicated by its name, this incinerator is used for liquids, but they must be atomized through a burner nozzle (Figure 10) so that solids, sludges and slurries of highly viscous liquids are not combustible in this equipment. Obviously this incinerator is extremely specialized and would warrant consideration only when such equipment is required. It is the most common hazardous waste incinerator. In 1981 more than 60% of the 342 incinerators in operation in the United States were of this type [30].

Figure 9. Fluidized bed furnace. From Reid, Crowther et al. 1980.

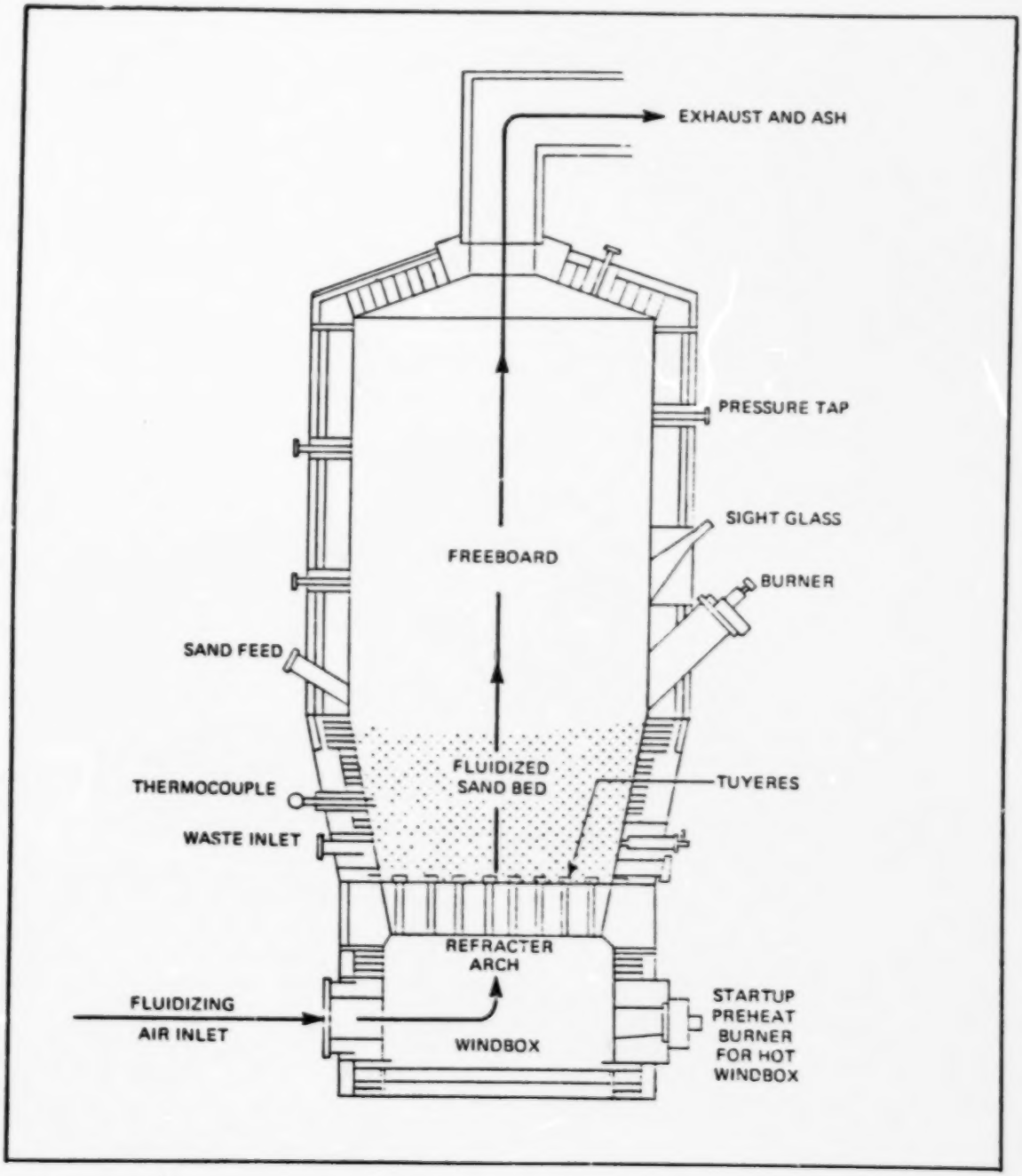
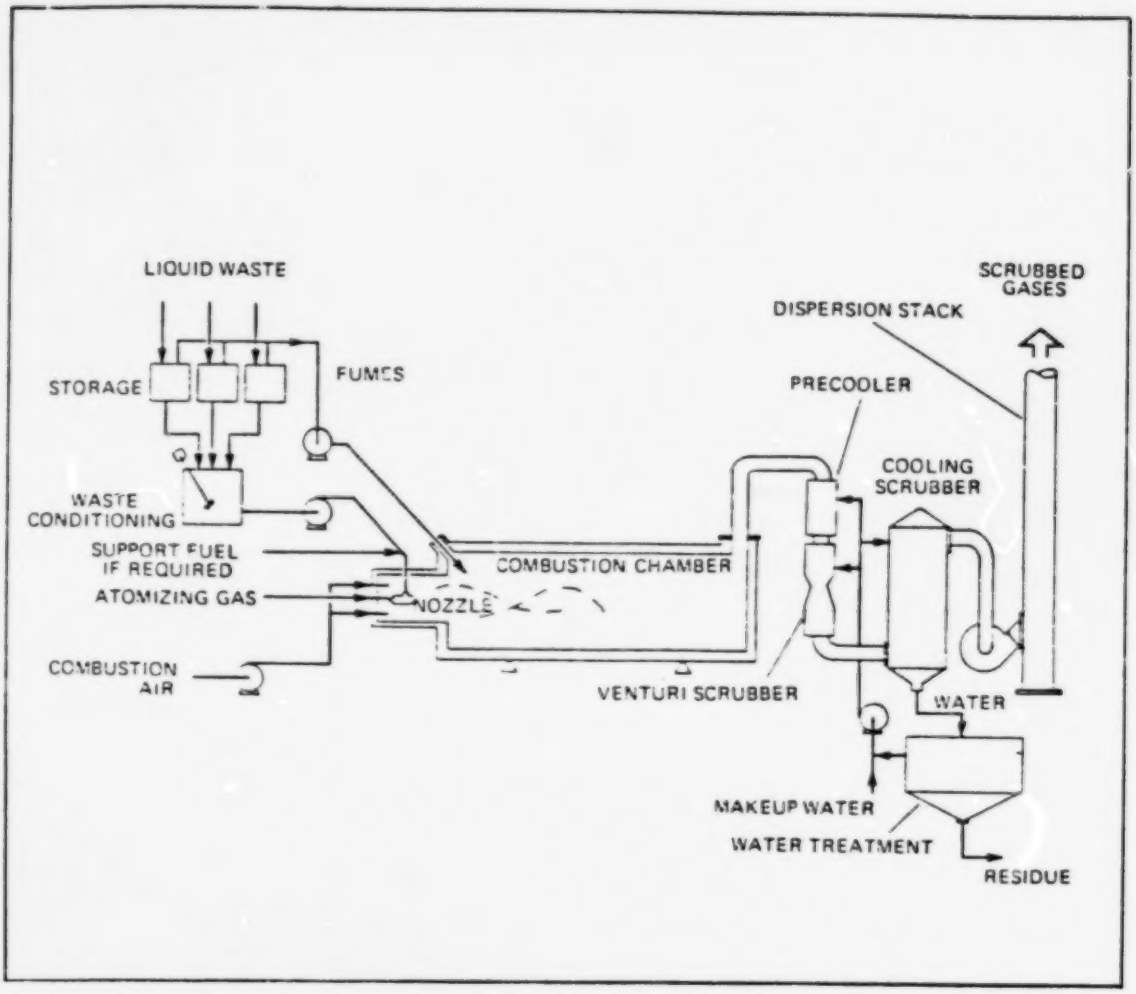


Figure 10. Liquid incineration. From Reid, Crowther et al. 1980.



Molten-Salt Incinerator
A molten-salt incinerator (Figure 11) is similar in appearance to a bell jar. Its operation depends on the ability of sodium carbonate and/or potassium carbonate to dissolve various substances and to act as catalysts for their oxidation. The wastes are introduced into the molten salt by a control cylinder. The exhaust gases exit via the top of the combuster. Two main limitations apply to this technique: one that it is not readily adaptable to aqueous wastes and the other that residue disposal (i.e. salt) may result in a leachate problem. Rockwell International, California with 25 years of experience in this process still regards it as requiring "further development, pilot testing and demonstration . . . before the process is ready for commercial utilization" (pers. com. July, 1984).

Multiple Chamber Incinerator
This incinerator is widely used in industrial and municipal situations for such solid wastes as paper, wood, refuse, and rubber. Three separate chambers are typical for this incinerator (Figure 12), — ignition, mixing, and secondary combustion chambers. The average temperature, however, is not high enough for the destruction of many hazardous wastes.

Multiple Hearth Incinerator
Although designed in 1943 for combustion of sewage plant sludge, the multiple hearth incinerator (also known as the Herreshoff furnace) Figure 13, is quite versatile in that it can also handle tars, solids, gases and liquids. The main feature of this incinerator, is its "multiple hearth" — a vertical series of zones or chambers through which the waste feed is moved by rotating horizontal plows. Air and combustion products rise to the top of the incinerator, thereby passing countercurrently to

Figure 11. Molten-salt incinerator. From Reid, Crowther et al. 1980.

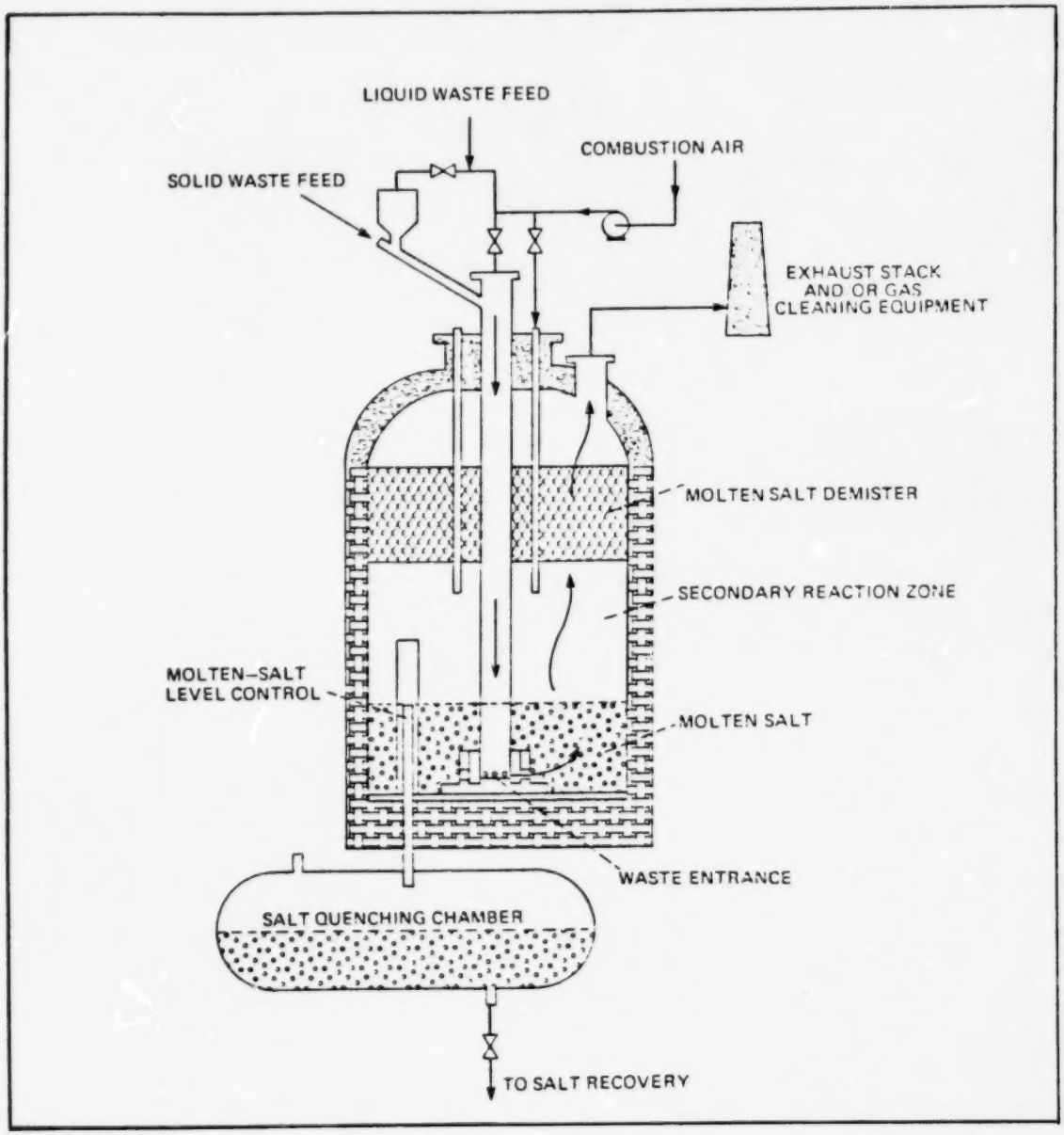


Figure 12. Multiple chamber incinerator. From Reid, Crowther et al. 1980.

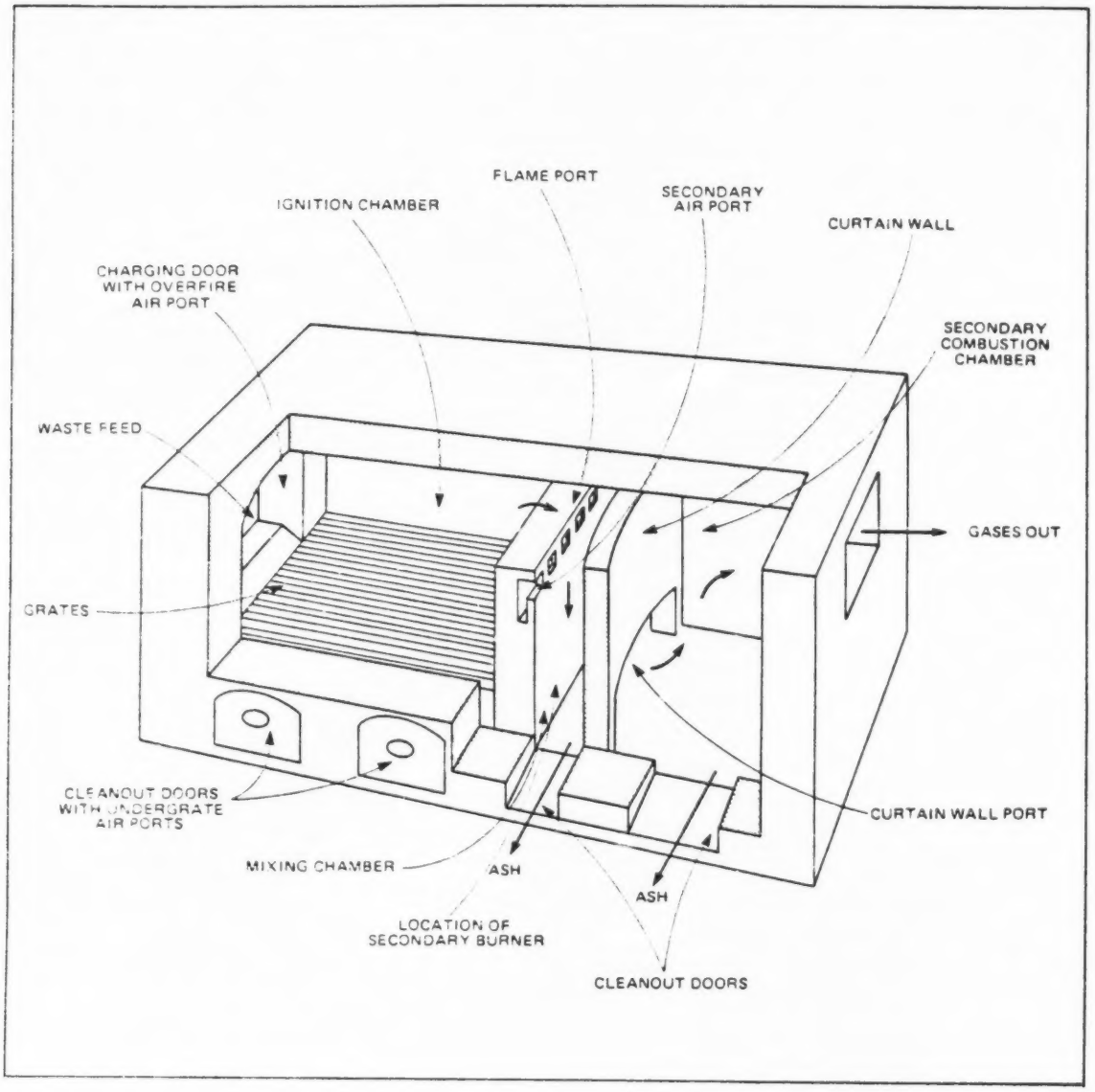
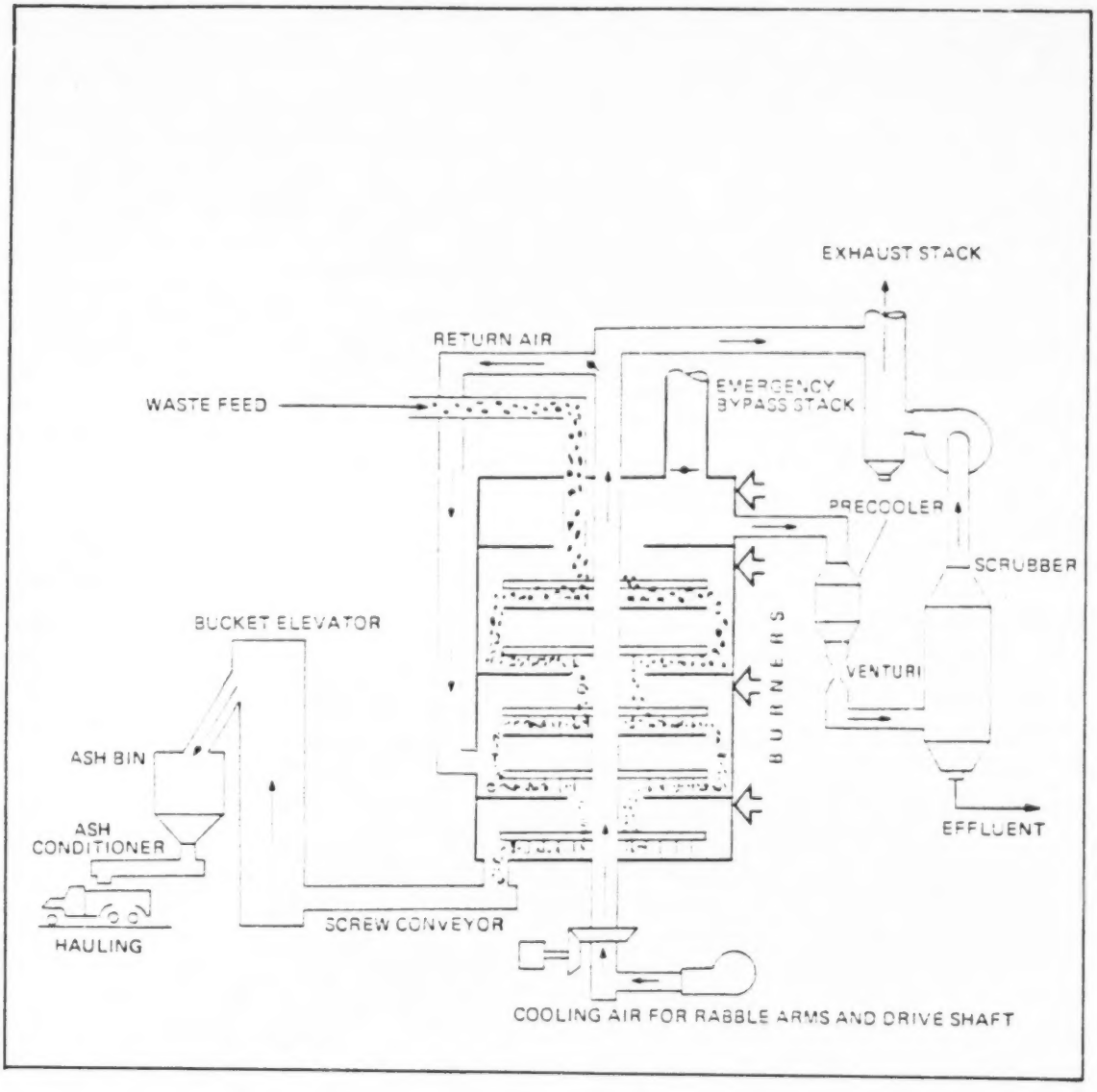


Figure 13. Multiple hearth incinerator. From Reid, Crowther et al. 1980.



the feed. Three disadvantages [2] of this incinerator are: a) high maintenance costs because moving parts are subject to combustion conditions; b) it is incapable of operating at elevated temperatures; and c) removal of fused incinerator ash is difficult.

Pyrolysis Incinerator

This incinerator differs not in the equipment but in the amount of air supplied for combustion. Pyrolysis is combustion in absence of oxygen. When combustion occurs between pyrolysis and oxidation, it is termed starved air combustion or thermal gasification. Pyrolysis is of interest because it not only detoxifies organic waste, but does so in a manner in which products might be recovered for reuse as chemical feedstocks or as fuel [4].

Rotary Kiln Incinerator

This incinerator (Figure 14) mounted on a descending horizontal plane, rotates so that air mixes with the waste feed as it is transported along the kiln. A typical kiln is 5 m (16 feet) long by 3m (10 feet) in diameter and can be used for solid, liquid or gaseous combustible wastes. It is the major incinerator type for hazardous waste [2] and has established itself as a universal incineration system [31].
Probably its most important advantage is that it represents proven technology. A major disadvantage is its hign capital cost. Portable units have been marketed, being mounted on a movable skid or truck body.

Incinerator Capabilities

Various incinerator types operate at different temperatures (Table 20). The greatest range attained is 1100° C (2000° F) but is not achieved by any one incinerator. The multiple hearth incinerator attains the lowest operating temperature. The highest operating temperatures are achieved by the rotary kiln and liquid injection incinerators. The former also has the greatest range. The multiple chamber incinerator has the shortest residence times; liquids and gases are combusted in seconds while solids are consumed in minutes. Once the materials to be incinerated are known, an informed choice of the appropriate incinerator for a hazardous waste facility can be made using Table 20.
Although each type of incinerator has advantages and some disadvantages there are some general limitations to their use [32].

1. In general, only organic materials can be incinerated although some inorganics can be thermally degraded.
2. Organics containing chlorine or other halogens emit corrosive gases. Appropriate incinerator construction materials must therefore be installed and suitable emission scrubbers must be in operation.
3. The presence of dangerous heavy metals (e.g. mercury, arsenic, selenium, lead, and cadmium) in inorganic wastes dictates caution in their incineration. These heavy

Figure 14. Rotary kiln incinerator. From Reid, Crowther et al. 1980.

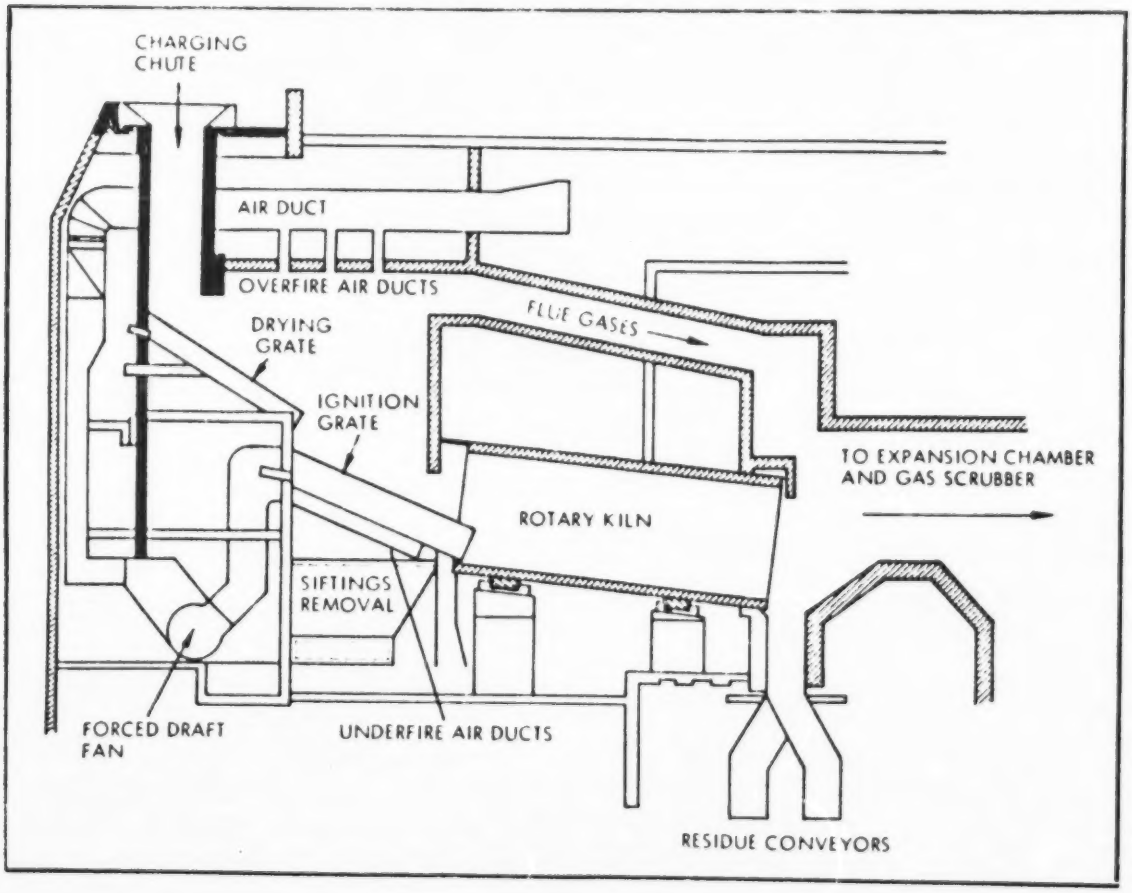


Table 20: Incinerator operating parameters

Type	Temp. Range (°C)	Dif.	Residence Time
Multiple Chamber	540 - 980	440	Liquids & gases: seconds Solids: minutes
Multiple Hearth	760 - 980	220	0.25 - 1.5 hours
Fluidized Bed	760 - 980	220	Seconds - hours
Rotary Kiln	820 - 1650	830	Liquids & gases: seconds Solids: hours
Liquid Injection	980 - 1650	670	0.1 - 2 seconds

After Kiang and Metry 1982 [19]

metals may be vapourized, appear as particulates, or as an oxide in the ash. In any case, the appropriate strategy must be employed so that these metals do not persist as an environmental hazard.

4. Sulphur-containing organic materials usually form sulphur oxide upon incineration. They should be removed from the stack gases to avoid the formation of sulphurous and sulphuric acids.
5. The amount of a material destroyed by incineration (i.e. destruction ratio) is largely dependent on the relationship between incineration temperature and "dwell" time at that temperature. The higher this temperature; the shorter the dwell time to effect a given destruction ratio. Most hazardous organics can usually be completely destroyed by a 1000° C (1830° F) temperature for 2 seconds. Some are destroyed at lesser temperature/dwell times while a few require more severe conditions. Obviously incineration of hazardous materials should not be carried out unless their destruction conditions are known.

Incineration for Manitoba

Unless our hazardous waste is shipped to another jurisdiction for treatment and disposal, it must be treated within the Province as interim storage is only a stop-gap measure. Incineration should be considered as one of the treatment techniques. From this review of the various types of incineration, it is concluded that the incinerator chosen for Manitoba should be versatile, proven, and dependable. Expense is a possible deterrent but this disadvantage could be offset by treating a wide variety of hazardous wastes in an environmentally acceptable manner. To accomplish this, appropriate pollution control equipment must be installed to handle its combustion products.

Although no calculations involving quantities of burnable hazardous waste have yet been made, currently the implicit assumption is that only one incinerator is required. If installed with overcapacity for hazardous wastes, it could also be used to burn municipal waste. Studies [15a & b] indicate that a refuse-burning steam generating plant was a possibility for the City of Winnipeg. Because of the obvious financial and other benefits of destroying both hazardous and municipal waste in one incinerator, such an option should be seriously considered at the planning stage.

A mobile incinerator has been proposed [18]. "There was thought to be a need for mobile units such as a rotary kiln for on-site treatment of contaminated soils, for example." Obviously its feasibility cannot be accepted until the feed load and other factors pertaining to the main incinerator have been documented. However, it should be considered as a possible tool in the management of Manitoba's hazardous waste.

Secure Landfill

Very few substances designated as hazardous waste can be disposed of without some form of pretreatment procedures designed to render innocuous some of the more harmful elements of the waste. This pretreatment may include all of the methods previously reviewed in this section. Any form of hazardous waste pretreatment will leave some residue: ash, sludge, solid or liquid. Further encapsulation and/or solidification of many of these residues will allow for disposal in a secure landfill.

It is evident that any system designed for the treatment and disposal of hazardous waste will have to be accompanied by a secure landfill site which reduces the associated risk to public health and the environment.

The design, location, and operating features of any secure landfill are often governed by regulations implemented by local, provincial, or federal governments. Manitoba Regulation 208/76 under The Clean Environment Act respecting solid waste landfill sites outlines the design and operating criteria for waste disposal grounds. Regulations in direct relation to the landfilling of hazardous wastes will be developed under the Manitoba Dangerous Goods Handling and Transportation Act. Other (e.g. local or municipal) regulations, may also apply to the siting and design of secure landfill sites, depending on the selected location.

Site Selection

Considerable planning must be undertaken before a suitable area can be selected for use as a hazardous waste landfill site. One of the biggest considerations when siting this type of facility is public acceptance. An active public information program describing the facility, what it will be used for and what it can and cannot do, the financial aspects of the operation, and a well designed final use plan that assures absolute public safety is essential.

When selecting a potential site for secure landfilling a number of preliminary criteria must be considered, reflecting concerns over public health, the environment, and the cost effectiveness of the potential sites [42].

Size requirements for the facility should be worked out in the preliminary planning stages: the required amount of land; space for adequate environmental controls; a buffer zone around the site; and enough room for future expansion. The amount of land available for a site may be dependent on a such factors as zoning restrictions and current land use.

Another consideration is site access. Transportation routes through population centers as well as routes with steep grade, narrow bridges, and low underpasses should be avoided. Sites must be easily accessible to vehicular traffic in all weather, and possibly located near rail lines. The proximity of waste generators is another important economic factor with respect to hauling distances.

Consideration should be given to the availability of cover material for compaction under and over the wastes. Porosity, permeability, compaction, and workability tests on the available soils will indicate their suitability. Hauling distances for cover material are yet another cost factor to be considered when siting.

One of the most significant environmental threats is the potential for pollution of the ground and surface waters located near a hazardous waste landfill site. Any site selection process should include detailed geologic, hydrogeologic and hydrologic evaluations designed to eliminate any areas exhibiting pathways for leachate migration. A study of the topography associated with candidate areas will eliminate other physical features of environmental concern, such as wetlands, floodplains, lowlands, and possible groundwater recharge zones.

The climate is another consideration in the overall siting process. Areas subject to permafrost, severe runoff, or water ponding at surface during heavy rainfall or spring thaws are unsuitable candidate sites.

Site Design

Design of the required facility should incorporate any specific protection, monitoring, and control devices required to ensure the safety of the public health and retain the integrity of the surrounding environment.

Generally a secure landfill for hazardous wastes consists of a containment cell with impervious sides and bottom within which the hazardous wastes are deposited. When the cell use is to be terminated the top is closed with impervious material in order to complete the containment.

Figure 15 is a plan view of a typical hazardous waste disposal facility. An area of inactivity known as a buffer zone, owned and operated by the disposal facility, must be obtained to ensure public safety. Site specific considerations and land availability govern the width of the zone.

The entire disposal facility must be secured with a fence to discourage unauthorized access and secure locking gates must be maintained at all entry points.

The facility should be surrounded by a shelter belt consisting of a visual screen of trees and shrubs, both for aesthetics and for erosion control. An earthen berm serves to deflect wind and contain site noise and debris.

The area designated for actual landfilling of hazardous waste will include a number of design features that will enable the operator to inventory and control the wastes, isolate them if necessary, implement the landfilling, and protect surface and subsurface environments. Figure 16 shows two cross sections of a hazardous waste disposal facility: during use, and after site termination.

Figure 15. Plan view of a secure landfill site for hazardous waste.

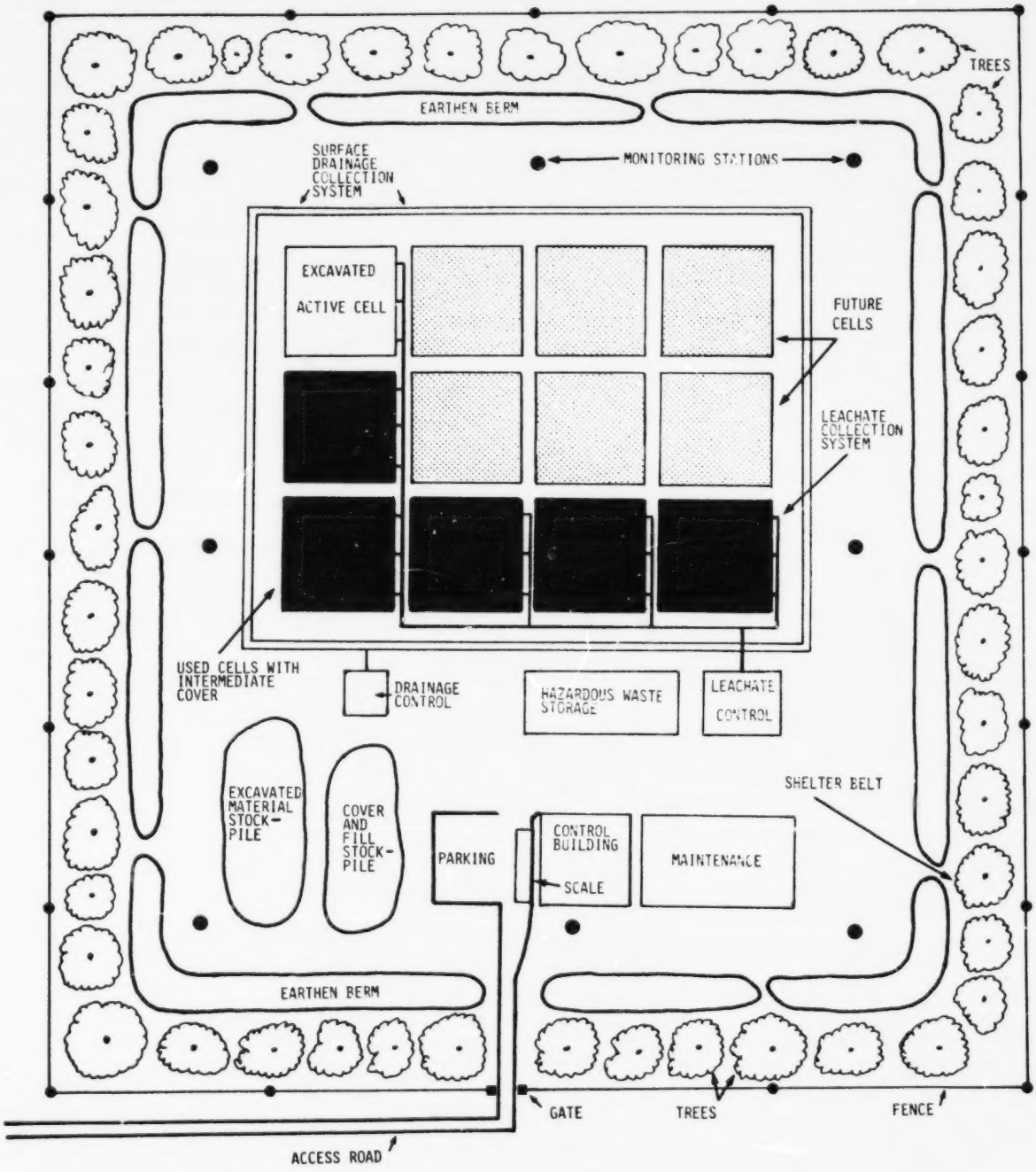


Figure 16. Cross section of a secure landfill site.

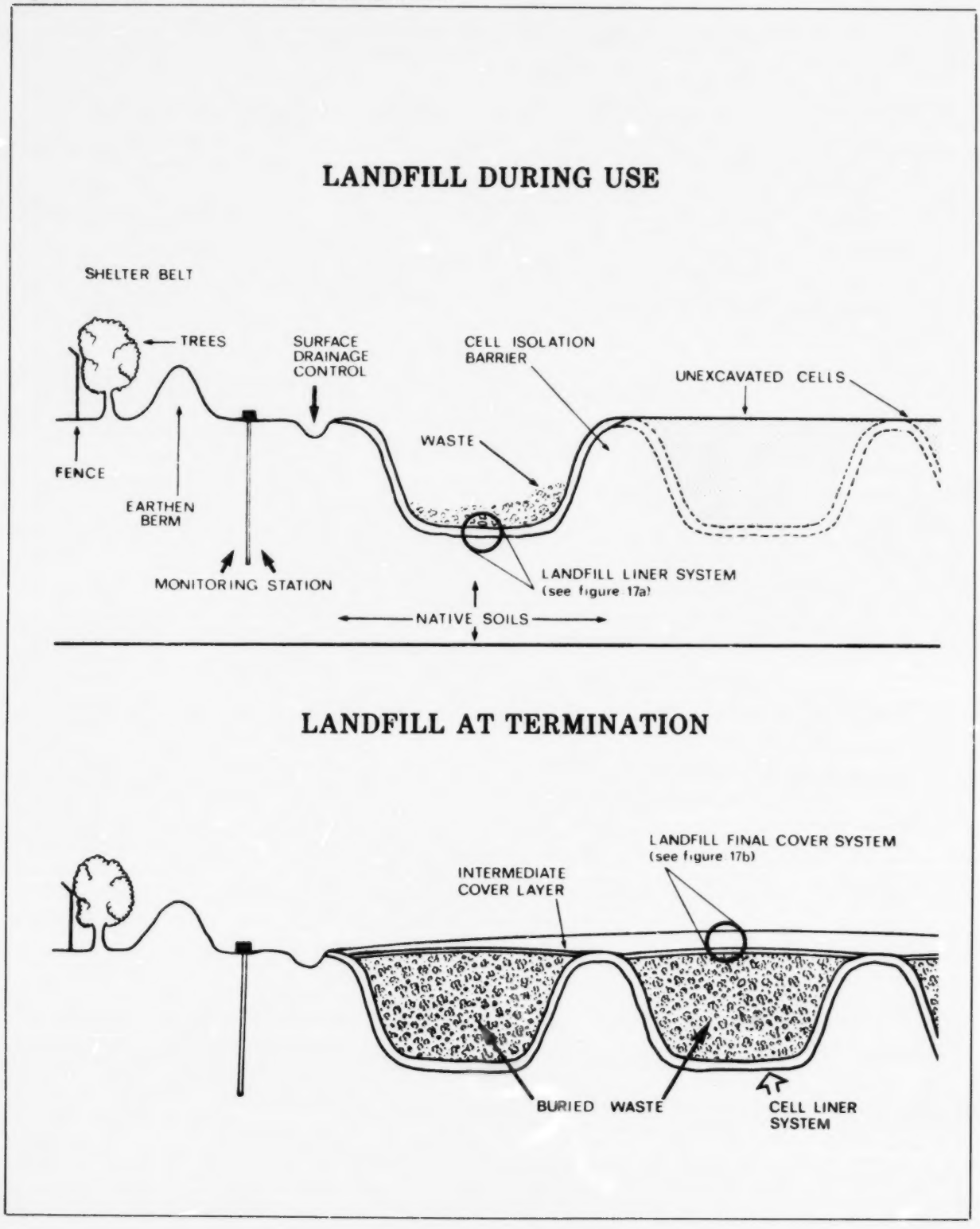
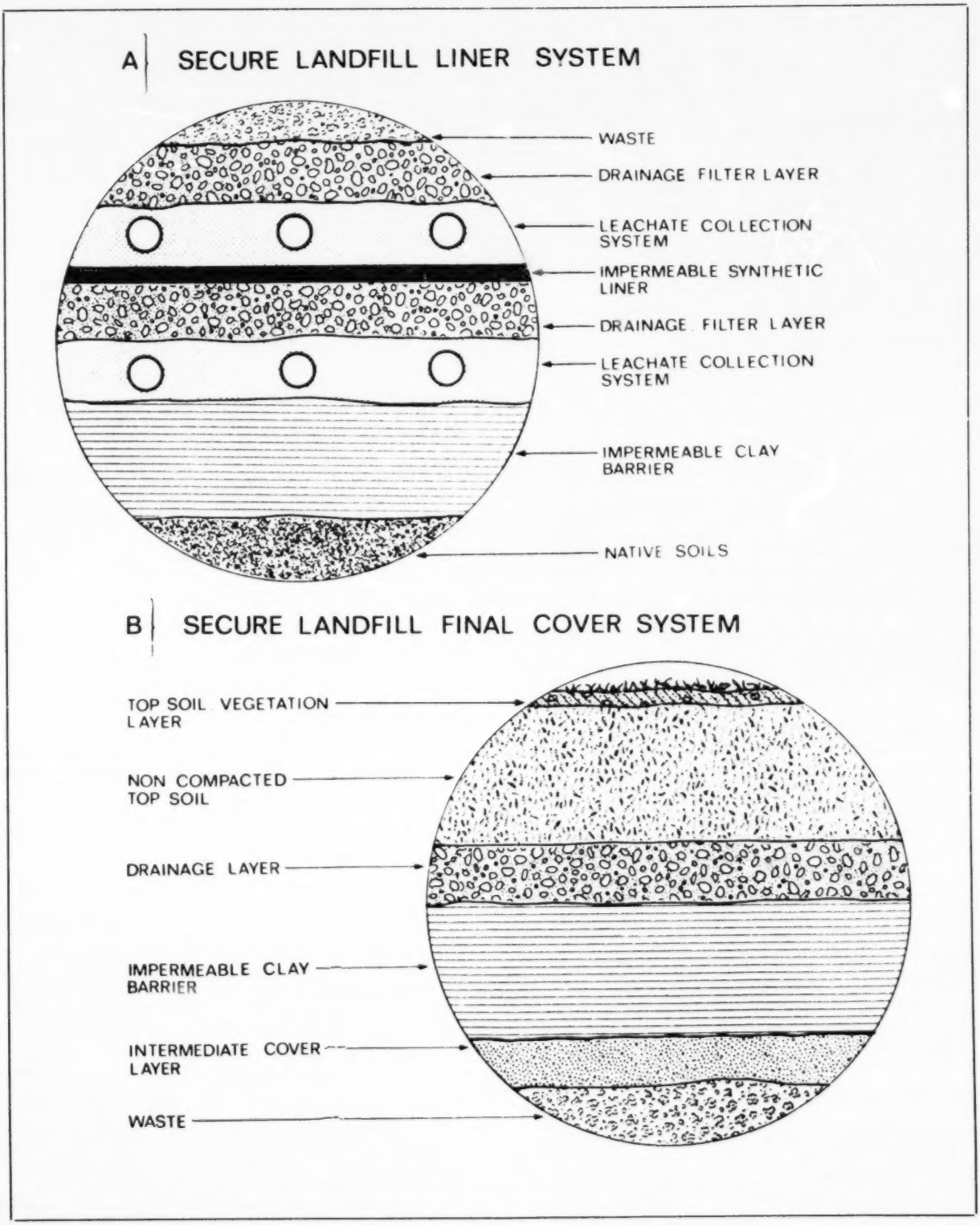


Figure 17. Liner and cover system for a secure landfill cell.



On-site facilities should include a control building and scale to monitor waste and traffic, a parking area near the entrance for all vehicles not necessary for waste handling, a maintenance building to house staff and equipment, a building for interim storage of hazardous waste, and areas to stockpile both materials excavated during site preparation and additional cover and fill materials.

A secure landfill should consist of a number of isolated cells. By dividing the area into separate compartments or cells, individual control and monitoring of the various hazardous wastes becomes possible. Each cell must have an impermeable liner mechanism designed to reduce the risk of leachate migration into the subsurface environment. Because pollution of groundwater from landfill leachate is a major concern, this liner system should include a mechanism for collecting any leachate produced. The collected leachate must be handled, pretreated and disposed of as any other liquid hazardous waste (Figure17a).

Stations designed to monitor groundwater for possible leachate migration should be set up throughout the site, including the surrounding buffer zone. These stations will continue to be monitored after the land filling is terminated.

As each cell of the landfill site is completed, a sloping intermediate cover must be placed over it to facilitate the runoff of rainwater which otherwise may percolate through the waste and aid in the production of leachate. When the site is to be terminated, a final impermeable cover system must be placed over the entire active landfill area [33]. This will discourage any infiltration into the waste cells and preserves the integrity of the secure landfill. Figure 17b shows the design of the final cover system.

Figure 17 represents only one of many possible designs for landfill liner and cover systems. Figure 17a illustrates a two-layer drainage and leachate collection system separated by a synthetic liner and overlying a fairly thick impermeable clay barrier. It may not be necessary to include both layers depending on the requirements of the landfill. Figure 17b is a final cover system designed to secure the landfill from infiltration after termination of the site as a hazardous waste facility. The drainage layer illustrated here is required to remove rain or melt water. A synthetic liner may be included in the cover system, again, depending upon the requirements of the design.

A surface drainage collection system should be included, to control surface run-on from mixing with the wastes during active operation, and to collect run-off from the final cover after termination of the site.

Economics

As a preliminary step, providing some comparative costs between disposal techniques appears useful. Costs for "the Western European Chemical Industry" in 1979 are shown in Table 21 [31]. Land disposal is the cheapest method ($1 - 20/tonne) which doubtlessly explains its prevalence. Simple incineration at $30 per tonne can be as little as 50% higher than land disposal. The increased cost to incinerate with pollution control equipment in place is to be noted. Chemical methods are usually costlier than simple incineration, ranging from $100-500 per tonne. Other comparisons have been made [11]. Quantities are in tonnes and dollar values refer to 1981. To incinerate clear liquids, the range is $13-53; to incinerate solids or highly toxic liquids, the price range increases to $400-800. Landfilling costs vary with the material. For acids/alkalis, the cost ranges between $13 and $200; for odorous waste, the cost is $30 while for low risk material, e.g. oils, the range is $13 - $30. Chemical treatment cost of acids/alkalines ranges between $21 and $92, while it can vary from $66 to $800 for highly toxic wastes such as cyanides.

Table 21 Cost of waste treatment and disposal

Method	Cost range (U.S. $/tonne)
Simple land disposal	1 - 20[1]
Land disposal - plastic sheet lined site	10 - 50
Land disposal after encapsulation	10 - 100
Simple incineration (no heat recovery)	30 - 150
Incineration - Alkaline Stack Scrubbing	100 - 350
Chemical Treatment	
reduction of chromic acid	100 - 300
destruction of cyanide (catalytic)	200 - 250
destruction of cyanide by hypochlorite	300 - 500

[1] Transport cost for long distance not taken into account

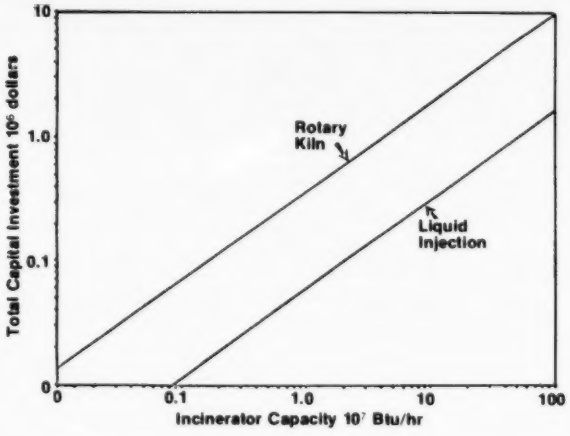
From Suess and Huismans 1983 [32]

Incineration Costs

It is impossible to be precise regarding the cost for a Manitoba hazardous waste incineration facility. There are several reasons for this. Firstly, too few units are in operation to provide a clear picture of incinerator economics. In the United States, according to Samuel Epstein [11] there are currently only 15 controlled high temperature incinerators suitable for disposal of hazardous wastes. Secondly, many variables can influence these expenditures. Should peripheral equipment (See Figure 8) for the incinerator be included? Finally, incinerator size depends upon the amount of feed materials, itself dependent upon the quantity of hazardous material produced and extent of chemical and/or physical pretreatment.

Costs relative to several incinerator types have been compiled [30]. Unfortunately they apply to different materials and have dissimilar variables so that the comparisons resemble "apples and oranges." Incineration by liquid injection can be quite variable. To dispose of ethylene and hexachlorocyclopentadiene, the cost ranged from $69 to $493 per tonne. In a fluidized bed incinerator, the cost of incinerating two wastes (phenol and methyl methacrylate) was $141 and $242 per cubic meter. The destruction of nitrochlorobenzene and PCB's in a rotary kiln was $283 and $741 per tonne. All these costs included capital charges for the equipment. In 1977, the capital investment for two of these incinerators at Van Nuys, California was 1.6 and 1.8 million U.S. dollars [30]. A graph for estimation of capital costs for two incinerators is presented (Figure 18). The basic assumptions have been recorded [2]. Unfortunately the final amount could vary by 100% so that a unit estimated at $1.0 million could cost from $500,000 to $1.5 million. However, incinerator capacity is rarely calculated in heat units/hour. The more usual measure is feed tonnage per year. Nevertheless the graph usefully compares two incinerators. A rotary kiln incinerator is twice as expensive as a liquid injection one.

Figure 18. Capital costs for two incinerator types.



System Costs

Obtaining operational costs for an integrated hazardous waste management system is difficult as very few are currently in operation. A system, operating in Bavaria, Germany is highly regarded and statistics on it are available [13].

The "G.S.B." or "Company for Disposal of Special Waste in Bavaria, Ltd." commenced operations in 1970. Bavaria has about 11 times the population in one eleventh of Manitoba's size. Considering this small area, it is surprising that the company operates 7 collection and 3 treatment plants for its hazardous wastes. The magnitude of its operation is substantial. In 1978, G.S.B. received 183,042 tonnes of waste. In 1979, there were 185 persons on staff and the estimated operating expenses were $17.2 million.

The central treatment plant at Ebenhausen has a staff of 76 and facilities for physical/chemical treatment (capacity of 29,000 tonnes/year), waste water treatment, and incineration (capacity of 25 gigacalories/hr. or 60,000 tonnes/year). Incineration is by two rotary kilns - the largest waste incineration plant in Germany. It's landfill site, with a 20 year storage capacity, is 64 km away. A third rotary kiln incinerator (capacity of 9 G cal/hr., circa 24,500 tonnes/year) is at Schweinfurt, 25 km away.

A substantial capital investment initiated the G.S.B. system. Since 1970, about $53 million has been spent for capital works including land and buildings. The largest expenditure, $39.6 million, was for the facilities at Ebenhausen and Gallenbeck. It can be partitioned in $ millions as follows: incineration (17.3), physicochemical and waste water treatment (6), Gallenbeck landfill site (3), other expenditures, i.e. land, workshop, lab, site preparation (23). These are 1974-75 costs and therefore would be much higher 10 years later.

Various operational costs are detailed in Table 22. Solvent recycling is the single largest expense, three quarters of the total costs of $908/tonne. Other costs are each less than 10%, except incineration, the next most costly process, being $109/tonne (12%). Collection costs i.e. gathering and transportation, come to $17/tonne, a very reasonable figure. It's low cost undoubtedly is related to short hauls of high volume materials.

Table 22: 1979 costs for G.S.B. hazardous waste management system

Function	Cost/tonne $	Cost %
1) Gathering	5.77	<1
2) Transportation	11.39	1
3) Waste water treatment	15.10	2
4) Physicochemical treatment	59.53	7
5) Solvent recycling	682.90	75
6) Incineration	109.29	12
7) 3rd party disposal (salt-mine)	12.70	1
8) Land filling	11.63	1
9) Head office	.13	<1
TOTAL	908.44	100

From Hu Harries and Associates, Ltd. 1979, [13]

The total income received from waste treatment in 1978 was $16.4 million, providing a net income of $816,000 and reducing the deficit to

$3.9 million. The company policy is "no profit." G.S.B. apparently is a very efficient company. It could not operate so efficiently without good management, diligent staff, and approval of the community at large.

The estimated operating costs for the proposed Alberta system are stated in Table 23 being calculated from the G.S.B. figures. Neither figures take into account capital costs. Even neglecting transportation costs, the Alberta processing costs are considerably lower, about 50%, than the G.S.B. ones ($611 versus $908/tonne).

Table 23: Alberta estimated hazardous waste operating cost

Item	Cost[1] $/tonne
1. Gathering	5.75
2. Waste water treatment	10.15
3. Physicochemical treatment	24.66
4. Solvent recycling	475.00
5. Incineration	67.40
6. Disposal untreated material (salt-mine)	11.37
7. Landfill	5.11
8. Administration	11.44
TOTAL	610.93

[1] = Excludes capital and transport costs
From Hu Harries and Associates Ltd. 1979 [13]

Unfortunately no precise figures have been found for a central disposal facility in Alberta. One opinion [13] was that it "may be in the order of $20 million and perhaps as high as $30 million." The Manitoba Symposium . . . was told [18] that "such a facility could end up costing 50 million dollars." Apparently a rotary kiln incinerator will be used in Alberta [18].

Site selection currently is the major activity of Ontario hazardous waste management program. Little information is available on the economics of their treatment facility. Its capital cost "will be in the neighborhood of 80 to 100 million dollars" [18]. These facilities are being designed for a capacity of 150,000 tonnes/year with a future expansion up to 300,000 tonnes/year. Dr. Donald Chant believed it will be "the largest treatment facility anywhere in the world, even at 150,000 tonnes." A rotary kiln incinerator is the choice of the Ontario Waste Management Corporation consultants [28]. The Ontario Waste Management Corporation established the following three key principles to guide its decisions on facility size and capacity [27]:

> The initial installation should be capable of expansion through designs that leave room for new construction, equipment that allows for modular expansion, and technologies that favour increased capacity through extra shifts, wherever practical, rather than new construction of additional installations.
>
> To avoid the design of wasteful excess capacity because of the uncertainty inherent in market estimates, the initial capacity of the facilities should be lower than OWMC's estimate of the final quantity that ultimately will come to its facilities.
>
> Nevertheless, the initial capacity should be large enough to make a significant impact on the problem of special waste in Ontario, particularly the most potentially hazardous waste streams, and to allow all treatment components to operate efficiently.

These three principles are sound and are recommended for application to a hazardous waste management system in Manitoba.

7. Management System Options for Manitoba

The basic objective of any conceptual system for Manitoba is to develop a comprehensive hazardous waste management system which will accommodate all of the hazardous waste generated in Manitoba and which incorporates waste reduction, reuse, and recycling in its operation. Based on the information in this report, 5 basic system concept options are proposed to meet this objective:

1. use of upgraded existing facilities and technology;
2. out-of-province disposal;
3. development of regional special facilities;
4. development of integrated (centralized) special facilities; and
5. combination of these concepts.

These options are presented in Table 24 for quick comparison, and discussed in more detail in this section.

standards. Collection stations and transportation networks are necessary to ensure efficient handling of all hazardous waste throughout the province. Recycling is one means of reducing treatment and disposal costs and of reclaiming potentially valuable resources. Legislative enforcement ensures compliance with the regulatory framework, e.g. the criteria for waste identification and classification, or the transport regulations.

The management system concept must take into account the types and quantities as well as the distribution of wastes, as identified in Section 2. By definition, hazardous waste includes a very broad spectrum of substances; in some instances these materials cannot be addressed by current waste management technology. An example of this situation is air emissions, which currently cannot be collected for treatment and disposal, being controlled instead through orders under The Clean Environment Act. There are, however over 20,000 tonnes of a wide spectrum of

Table 24: Options and requirements for Manitoba hazardous waste management system

	OPTION				
	1	2	3	4	5
General Requirements	Upgraded existing facilities and technology	Out of province disposal	Regional facilities	Centralized integrated facilities	Combination of options 1, 2, 3 (or 4)
Analytical support	some development	least development	most development	most development	most development
Collection stations	requires development	requires development	requires development	requires development	requires development
Transportation network	requires development	requires development	requires development	requires development	requires development
Recycling	least efficient	out of province	less efficient	greater efficiency	greater efficiency
Legislative enforcement	least efficient	requires development	more efficient	most efficient	least efficient
Special Requirements					
Site Selection process	none	none	several	one	several or one
Site Selection constraints	least	none	less	most	less or most

General Requirements

Any comprehensive hazardous waste managemennt system must address the general areas of analytical support, collection stations, transportation networks, recycling, and enforcement of the legislation. Analytical support is required for treatment and disposal, as well as to identify and classify wastes in order to meet legislative enforcement

substances in all classes (gases, flammable liquids and solids, oxidizers, toxics and corrosives) which will require handling.

The Winnipeg Region contains the greatest number of hazardous waste generators (186) and the largest quantity of waste (7881 tonnes/year). The Western Region has the second largest number of waste generators and quantity of waste. Although the quantity of

waste in the Eastern Region is the third highest, it is generated by only 3 companies. A similar situation exists in the Northern Region where 23 percent of the total waste is generated by 9 companies. In contrast, the Southern Region with 32 companies generates the smallest percentage of waste. These regional differences in the distribution of hazardous waste generators and quantities must also be reflected in the final concept of a management system for the province.

Option 1: Use of Upgraded Existing Facilities

In a way, this option simply reflects the present situation. Although the treatment and disposal of hazardous wastes usually implies the use of specialized technology and facilities, small quantities of these wastes can be handled by available conventional facilities. Conventional physical separation and biological degradation processes which are employed by sewage plants can treat some of the non-chlorinated organic solvents. Similarly conventional landfills, if properly situated and maintained, can accommodate some inorganic solid hazardous wastes. Some incinerators in Manitoba can safely handle pathological and other types of hazardous wastes [17]. These existing facilities, however, were not designed specifically for hazardous wastes. Therefore, significant upgrading (and changes to such support facilities as storage and handling) must be carried out if this option is chosen.

All of the infrastructure mentioned under General Requirements would still have to be developed. The assessment of current information as well as the past experience indicate that the diversity and volume of hazardous waste generated in the province is too great to be accommodated by the existing facilities and technology, even with upgrading.

Option 2: Out-of-Province Disposal

Experience has shown that limited out-of-province disposal can be accomplished, although costs are high. Small quantities of wastes are even now being shipped out of the province. For these, the provincial government operates an interim collection and storage facility, which serves primarily for acute toxic wastes (UN Class 6) collected from schools, hospitals, universities, and a few industrial sources (Table 10). Some pesticide residues retrieved from disposal grounds are also stored. This addresses approximately three percent of this UN Class or less than one percent of the total waste identified in Manitoba. For a valid out-of-province option, it would be necessary to build a network of properly designed collection stations and to designate transport routes.

Analytical support must be developed to identify and classify wastes prior to collection. This may be accomplished by upgrading the existing provincial laboratory or by contracting the analysis with certified private laboratories.

Recycling is usually part of the treatment and disposal package offered by out-of-province disposal companies. However, Manitoba would have no control over the type of recycling, and any economic spin-offs and incentives would accrue elsewhere.

The province would still have to enforce the Dangerous Goods Handling and Transportation Act, to register waste generators and storage facilities, and to license transporters of waste. It would also have to regulate the keeping and disposition of records, as well as the location, design, construction and operation of facilities and equipment used for handling dangerous goods. Due to transportation and liability costs, this option is somewhat limited in its long term applicability to all the identified wastes. Other jurisdictions limit acceptance of certain wastes, control licensing, and establish operating standards for facilities within their area. In 1980, the United States government closed its border to shipments of PCB wastes and some state governments accept imports of hazardous wastes only from limited geographical areas, usually close to their own borders.

The costs of implementing this waste management option would be significantly lower because treatment and disposal facilities and the related siting process would not be included. The actual disposal costs, however, would be controlled externally, by the out-of-province disposal facilities and by other jurisdictions.

Another significant factor to consider is the quantity and type of generated waste. The largest category, corrosives (74%) can be treated by physical/chemical methods which are less expensive than other technology, so that in the long term it may be more costly to transport the waste out of the province than to establish a treatment facility in Manitoba.

Option 3: Development of Special Regional Facilities

The general requirements for this option are essentially the same as indicated for Option 2 regarding analytical support, collection stations, transportation networks, and legislative enforcement. The important differences are in the area of recycling. With the development of specialized facilities, a greater emphasis may be placed on reuse, reduction and recycling of wastes as the system would be developed and controlled under a single legislative mandate.

Manitoba legislation will cover registration of waste generators and storage facilities, licensing of transporters of waste, record keeping, and location, design, construction and

operation of facilities and equipment used for handling dangerous goods. In addition, the licensing of disposal facilities will be regulated with public input through the public hearing process and the option of an environmental assessment and review.

The main disadvantage of Option 3 is that it requires siting of more than one facility; thus the associated costs will be higher than those for all other options. Another disadvantage would be the additional costs associated with segregating the wastes and transporting them to different regions for treatment and disposal. Option 3 could avoid duplication but instead of one integrated facility (as in Option 4), special facilities would be located in different regions to address specific wastes.

An advantage to this option would be the flexibility to adapt the location of special facilities to any particular site constraints — more easily done for individual facilities than for an integrated one. Another possible advantage would be that no one region would be responsible for the entire waste treatment and disposal process.

Regarding currently available technology, Section 6 indicates a wide variety of techniques and a wide range of costs. In terms of hazardous waste generated in Manitoba, technology is available to treat and dispose of most of the identified wastes.

Option 4: Development of Integrated (Centralized) Special Facilities

Much the same applies to this option as to Option 3. The important differences would be in the areas of cost and efficiency. An integrated facility would preclude more than one site selection process. With integrated technology, the costs of waste segregation would be minimized. Greater efficiency of recycling could be achieved, as all wastes would be directed to one location. Monitoring and enforcement would be accomplished more efficiently as well.

Both Options 3 and 4 have the distinct advantage of directly addressing the problem of treating and disposing of the hazardous wastes within our own jurisdiction. Along with the treatment and disposal aspects, recycling technology can be built into the system. It should be noted that for both Options 3 and 4 the facilities would be developed to address Manitoba's specific situation, and would have the capability of expanding, upgrading, and changing technology to address new wastes and new methodologies employed in recycling and reuse.

The disadvantages of Option 4 would be that one region would be responsible for all waste treatment and disposal and that site selection constraints would be greater than those for Option 3.

Option 5: Combination of Options

The strengths and weaknesses of each particular option have been covered in the previous discussions. A combination of options would strive to offset the disadvantages and strengthen the advantages.

Option 1 is deficient in that, even with upgrading, the existing facilities cannot address all the quantities and diversity of wastes. For certain types of hazardous waste, however, this option can be viable. The major disadvantages of Option 2 (out-of-province disposal) were lack of control over legislation, recycling benefits, and disposal cost, as well as higher transportation costs and uncertain availability of out-of-province disposal facilities. For both Option 3 and 4, the disadvantages were primarily the higher initial costs of both the site selection process and the construction of special facilities.

Option 5 would combine the useful features of Options 1 and 2 with those of either Option 3 or Option 4 (note that 3 and 4 are mutually exclusive). Wastes would be collected, analyzed and treated under uniform legislation. Special facilities to handle the large quantities of waste requiring less costly technology would be built either regionally (as for Option 3) or centrally (as for Option 4). Where high cost technology would be required for smaller quantities of waste, those wastes would be sent to out-of-province disposal facilities, if available. An example of this scenario would be the construction of facilities to deal with the corrosive wastes (which represent 74 percent of the total), some of the flammable liquid wastes, and the remaining categories of waste which requires less costly technology. The smaller quantities of waste which requires high cost facilities (e.g. highly toxic materials, or chlorinated solvents) would be sent out of the province.

The major advantage of this option is its flexibility and adaptability to Manitoba's specific conditions.

8. Concluding Statement

The types and quantities of hazardous waste generated in Manitoba have been identified. It is concluded that the current handling and disposal practice does not, in the long term, ensure adequate protection for the public health and the environment. The currently available technology for dealing with hazardous wastes is discussed, and five options for a management system concept applicable to Manitoba's specific situation are proposed. It is recommended that one of the outlined options be chosen for design and implementation during Phase Two of the Hazardous Waste Management Action Plan.

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